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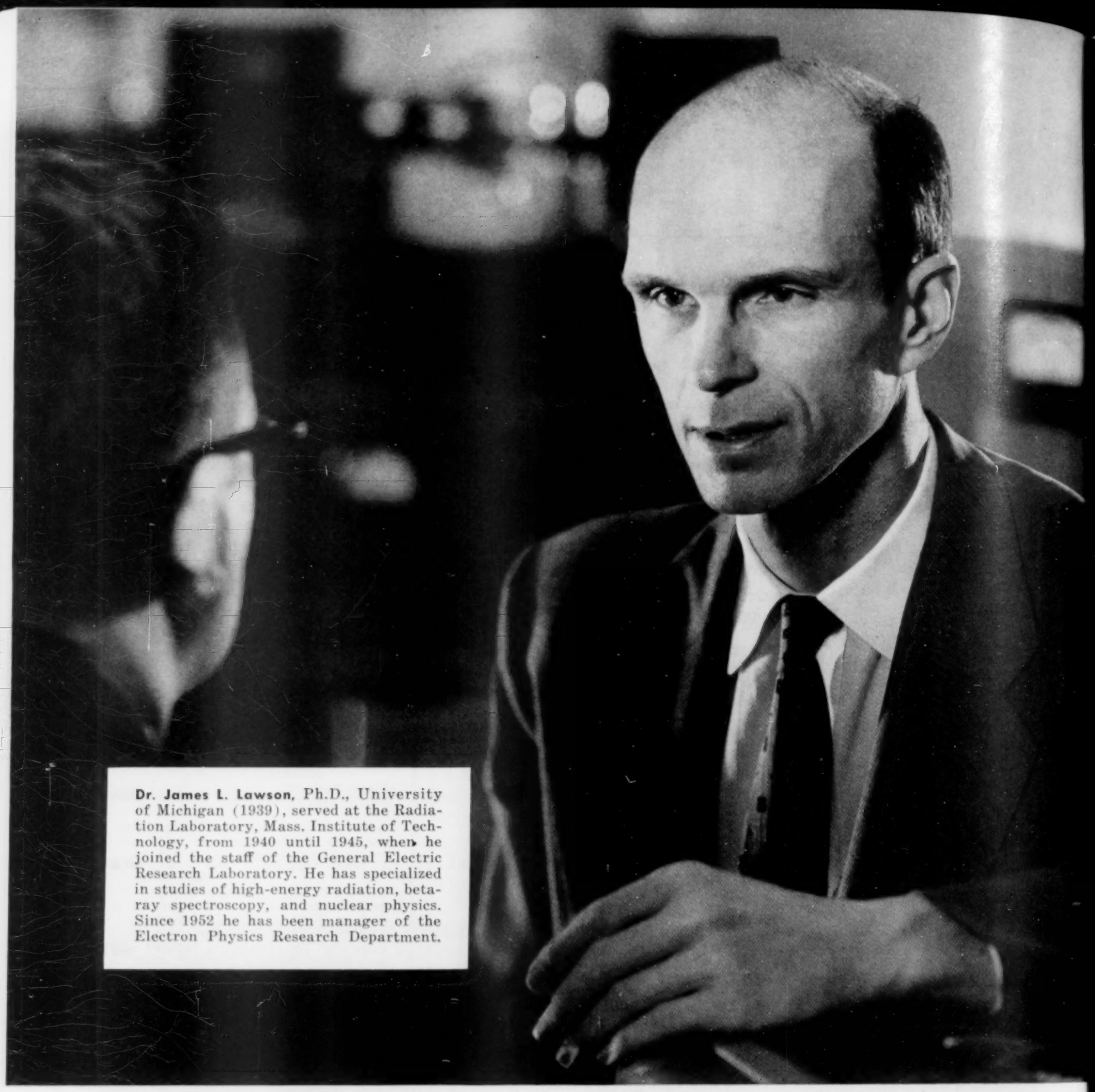

Dr. James L. Lawson, Ph.D., University of Michigan (1939), served at the Radiation Laboratory, Mass. Institute of Technology, from 1940 until 1945, when he joined the staff of the General Electric Research Laboratory. He has specialized in studies of high-energy radiation, beta-ray spectroscopy, and nuclear physics. Since 1952 he has been manager of the Electron Physics Research Department.

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Recommendations to Congress

Publication in this issue of the full report of the Association's recently held Parliament of Science will give readers a chance to judge for themselves what the Parliament accomplished. Press assessment has varied from reasonably enthusiastic praise to the strong criticism that while the Parliament discussed a number of important issues it usually did not carry the discussion to the point of making concrete recommendations about what should be done. Judgments about the holding of the meeting have been more uniform: most commentators have agreed that the effort itself was a good one and that the Association should be commended for bringing the thinking of scientists to bear on problems of science and public policy.

Such a meeting is one means through which scientists can express their judgment on matters of public policy, but it is not the only means. Individual judgments are also necessary, and individual judgments may be more specific in recommending action that the individual considers desirable.

There is now a quite specific opportunity to make known one's individual views on how the Federal Government can give the most help toward the improvement of education. Senate and House committees have held hearings on education bills and will soon report their recommendations—probably in the form of a new bill, or bills, embodying whatever the committees decide to retain of the original proposals. There is considerable uncertainty about how the various differences will be compromised, especially on one point. Last year and the year before, Congress defeated proposals that federal funds be used for the construction of new school buildings. This action was largely determined by the segregation issue; some members insisted that a segregation clause be included in the legislation; others refused to vote for the bill if a segregation clause was included; some saw a favorable vote on the segregation clause as a means of insuring ultimate defeat of the whole bill.

This year both of the major education bills [see *Science* **127**, 389, 21 Feb. 1958)] emphasize improvement of the quality of education and say nothing about school construction. School construction proposals are still very much alive, however, and it is quite likely either that this feature will be included when the bills are reported out of committee or that amendments will be offered during debate. Either way, the segregation issue will rise again. The result will probably be defeat for school construction funds and quite possibly for the other proposals as well.

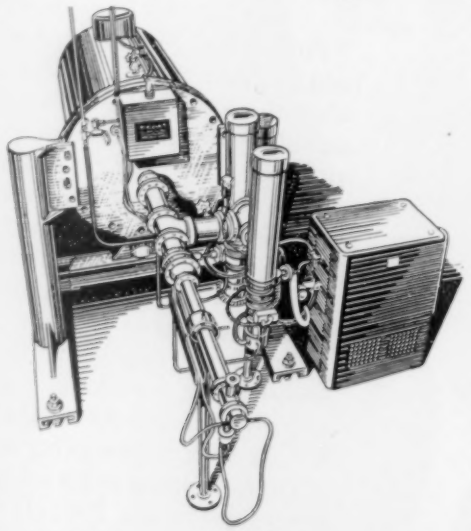
Supporters of the idea that federal funds can best be used to raise educational standards and to improve the quality of education are therefore faced with a problem of practical politics. Even though they may not oppose the use of federal funds for school construction per se, they have to decide whether to support or to oppose the addition of school construction proposals to the present bills. Support for the inclusion of money for school construction will probably not be strong enough to secure adoption of this legislation, and may indirectly help to defeat the other educational proposals. Opposition may appear to be a denial of one of education's real needs, but it may on the contrary actually increase the chances of getting the other proposals approved by Congress.

In the collective judgment of the Parliament of Science, efforts to improve the quality of teaching and education should take priority over the construction of more classrooms. The Parliament did not go beyond the statement of this principle, however, to indicate what actions should be taken in such a practical dilemma as the one that faces Congress. Scientists, together with faculty members in all fields and at all levels, have a major interest in how Congress resolves this problem. The members of Congress will be helped by knowing what individual scientists and educators recommend.—D.W.

The place of the Particle Accelerator in Basic Research...

The Effects of Ionizing Radiation in Liquid Systems - V

Determination of the effects of ionizing radiation in liquid systems is a challenging problem. Many physical models of the liquid phase have been proposed, and some success has attended their use. Although short-range molecular order appears to exist, complete disorder occurs at distances substantially greater than the molecule size, where the individual molecules wander through the system in a random manner[1]. This condition, combined with the difficulty of measuring directly the changes in physical and chemical properties of the liquid molecules, complicates the analysis of ionizing-radiation effects in liquid systems.



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Experimental Techniques

The experimental techniques usually adopted to study radiation effects are: measurement of the change of some solute in solution, or measurement of the yield of some product formed by the action of radiation. Analyses of radiation-formed products can be used to develop a mechanism for explaining the interaction of the incident radiation. Several Van de Graaff® accelerators, including those at the University of Notre Dame and the Brookhaven National Laboratory, are presently being used in studies of liquids under electron or x-ray bombardment.

Water Studies

One of the best-known liquids, which has received a great deal of attention from radiation chemists because of its importance in many radiobiological and radiochemical systems, is water. The generally accepted result of the interaction of a charged particle with a water molecule is dissociation, resulting in the production of free H and OH radicals. These may combine to re-form water or the molecular products H_2O_2 and H_2, or they may diffuse from the site of their formation to react with solute molecules in solution[2]. Studies of the kinetic behavior of these radicals have been important in analyzing many radiation-induced reactions.

A typical experimental method of studying the effects of these radicals is to investigate the radiation yield in the wet and dry states. This will give the percentage of radiation-induced changes caused by the transfer of radiation energy from the solvent molecules to the solute. The addition of scavenger molecules which compete with the solute for radicals will give some indication of the relative reactivity of the radicals.[3]

Energy Levels

Since the energy of dissociation of typical liquid molecules is of the order of tens of electron volts, while the energy transferred from the incident radiation may be many hundreds of electron volts, it is difficult to measure the direct effect on the individual molecules. Although values of ionization and excitation energy have been extrapolated from gas-phase studies, it is not easy to relate the effect of the molecular binding energy in the solution to the dissociation energy. About the best that can be done is to obtain as uniform as possible a distribution of radiation energy throughout the system and to assume that all secondary electrons have the same probability of interaction as the primary beam. The yield is then calculated in terms of the number of molecules changed per unit-energy input. The unit is the so-called G value which measures the number of molecules changed or formed per 100 electron volts.

Although the analysis of radiation-induced changes in liquid systems is complex, great strides have been made during the past few years. *With the availability of homogeneous beams of charged particles from Van de Graaff accelerators, which permit wide selection of energy and current values, it is expected that even greater success will be attained in the near future.*

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2. A. O. Allen, Rad. Res. 1, 85, 1954
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18 April 1958, Volume 127, Number 3303 SCIENCE

CURRENT PROBLEMS IN RESEARCH

Microwaves

They have important uses in defense projects, industrial developments, and basic physical research.

E. L. Ginzton

Although the term *microwave* is often encountered in the technical and scientific literature, it may be well to begin this review by restating the meaning of this term as it is known to the workers in the field. It is convenient to think of the electromagnetic spectrum as being divided into two parts which differ from each other in the methods available for the generation and detection of radiation. The first of these regions, that of shorter wavelength, is characterized by the fact that both generation and detection of radiation involve quantum effects (such as the radiation of light from an atom arising from the transition of electrons from one energy state to another). In this region can be listed cosmic radiation, visible light, infrared, and so on. The second part of the electromagnetic region, called the radio region, is characterized by the fact that electromagnetic energy can be generated by the circulation of electrical currents through conductors and, in contrast to the first case, the frequency of radiation can be controlled by selecting the size and configuration of electrical circuit elements. It is the extreme high-frequency end of the radio spectrum which is called the "microwave region," and these radio waves are called, for brevity, "microwaves." This qualitative definition of microwaves indicates that a clear distinction cannot be made between microwaves and short radio waves on the one hand, and microwaves and infrared radiation on the other.

At the present time, for various reasons which will be considered, it has not been possible in any practical way to generate radiation having a wavelength shorter than a few millimeters. The long-wave end of the microwave region is also vague, and microwave devices and techniques are occasionally used at frequencies which are attainable by refinement of ordinary radio devices and practice. Thus microwave principles and techniques are sometimes found useful at wavelengths as long as 100 centimeters. Expressed in units of frequency, the microwave region can be said to extend from about 300 megacycles to about 150,000 or 200,000 megacycles. This is a very large frequency domain, which provides room for many classes of radio service which find themselves crowded in the ordinary radio region which, by comparison, covers only a few hundred megacycles.

In considering the objectives of research in this field, it is important to observe that, in contrast to many branches of science, there is no intrinsic interest in conducting research in this field in itself. Whereas, for example, one can study cosmic particles in the hope that this study will shed new light on the basic properties and laws of nature, the study of microwaves in the same sense is pointless. The study of electromagnetic phenomena in the visible and radio regions during the last century has firmly established fundamental principles, and these, of course, govern the behavior of microwaves as well, even though the generation and observation of microwave phenomena did not become really practical until quite recently.

This does not imply, of course, that research which makes *use* of microwave techniques is not possible or profitable—quite to the contrary. The availability of electromagnetic radiation in the microwave region has opened up broad new areas of research in many fields. The significance of microwave research can perhaps be best understood by briefly describing some of the major fields of activity made possible by the development of methods of generation, detection, and measurement of microwave radiation. This will be attempted in the section on "Current applications" below.

It is important, then, to observe that research in the microwave field is clearly governed by the possible applications to which a particular discovery or development might lead. In other words, research in the microwave field must, of necessity, be *applied research,* always directed toward a useful goal in some other field. The fact that microwave research is of applied nature does not mean that the work is either mundane or of limited interest. Both the nature and methods of research are often most challenging, and it is gratifying that the results of the work frequently find application as both tools of fundamental research and in more conspicuous practical applications. Examples of the former are the use of microwaves in spectroscopy, in radio astronomy, and in particle accelerators; and of the latter, their use in radar, television relays, communications, navigation, cancer therapy, food sterilization, and home cooking ranges.

Since microwaves are radio waves, it is not surprising that the problems encountered in the field are those well-known in radio technology. These are: methods of generation and amplification of radiation; reception, detection, and amplification of incoming signals; and methods of measurement of the electrical quantities which are needed to describe accurately the behavior of electromagnetic waves in an experiment or system. Just as often happens in the ordinary radio region, many of the new

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microwave problems arise because it becomes of interest or importance to try to work at frequencies which have not been successfully used before; or to generate a greater amount of power than has been heretofore possible; or to try to find methods of amplification which would permit the detection of weaker signals, more closely approaching the theoretical limits imposed upon a given system by its temperature. All of these are practical problems, but their solution may permit, for example, a better understanding of molecular structure, or a novel astronomical observation.

In addition to describing the various applications of microwaves for the purpose of general interest, this article will be concerned with discussion of some of the problems that are encountered in finding means to generate, detect, and amplify power in a manner dictated by those applications which are now known to the workers in the microwave field. A more complete discussion of the principal areas of application of microwaves would be beyond the scope of this article.

Origin

There are four general reasons for the original and continuing interest in the microwave region. First, the development of successful methods of generation and detection of microwaves has made possible the investigation of certain classes of physical and chemical phenomena; microwave molecular spectroscopy is an example of one technique which is used in this work. Second, the wavelength of microwaves is so short that it is quite practical to build transmitting and receiving antennas which are large compared with the wavelength; thus, many principles of physical optics can be made to apply, and as a consequence, it is possible to focus and direct microwave radiation in a manner similar to that of light. Third, the wavelength of microwaves is still sufficiently long so that these waves, like ordinary radio waves, are not scattered and stopped by rain, fog, or clouds. Fourth, as mentioned before, the region between the shortest and the longest end of the microwave region is extremely wide in terms of frequency. Until the advent of microwave devices, all types of radio service had to be contained within a region of a few hundred megacycles. Consequently, the development of radar systems and of equipment for aircraft navigational and blind-landing aids and the expansion of communications of all types became feasible only after the microwave region of the spectrum became usable. The microwave region extended the frequency range available by a factor of approximately a thousand and will probably provide sufficient room for most of the foreseeable demands for many years.

It is difficult to present an accurate historical account of research in the microwave field because it developed slowly at first and extremely rapidly in the recent past. It is of interest to note that the first experimental verification of Maxwell's theories was carried out by Heinrich Hertz in 1888, and that this work was in the microwave region. In a series of now-famous experiments, Hertz demonstrated the feasibility of radio propagation and the identity of Maxwellian radiation and ordinary light by showing that, like light, "microwaves" obeyed the known optical laws of reflection, refraction, and polarization. These experiments were repeated by others, and, after a rapid improvement in technology, the first radio communication was established. In the course of the original development the primary interest centered on the problem of communication over long distances and, hence, the need for comparatively high power. This could then be obtained only at longer wavelengths, and the original "microwaves" were all but forgotten. Serious interest in the possible use of very-short-wavelength radiation did not begin until the mid-1930's, when it became increasingly evident that methods of rapid, precise detection of aircraft through fog, clouds, and darkness would be of great military value.

Development

From the time of the early workers in the field—Hertz, Lodge, Muirhead, Popoff, Braun, Tesla, Marconi, and others—to the beginning of the intense development work in the late 1930's, many significant contributions had been made by scientists throughout the world. The experiments of Hull with the split-anode magnetron in the early 1920's and the further development of this device by workers in Japan, made it possible to generate small but significant amounts of microwave power. In the early 1930's, work began on molecular spectroscopy, and this and related research led to further improvement in methods of generation, detection, and measurement.

Theoretical studies in the 1930's were also of major importance. Southworth and his collaborators at the Bell Telephone Laboratories, and Barrow at Massachusetts Institute of Technology, discovered the principles of guided propagation which eventually led to the widespread use of hollow pipes as a means of conducting electromagnetic energy from one place to another, instead of the wires which had been used before. The development of these transmission-line concepts was fundamental, since they made possible a system for transmission of high-frequency power without appreciable loss (which would otherwise be expected), and also because they provided an understanding of the behavior of electromagnetic waves in bounded regions. Another important contribution during this period was due to Hansen at Stanford University, who showed that empty or dielectric-filled containers could act as resonant circuits, just as the coil and condenser do at the lower radio frequencies.

In the middle 1930's the generation of microwave power in the amounts required for practical applications was difficult for two principal reasons. In all power-generating devices which use electrons it was considered necessary that the flight-time of the electrons across a given electron tube be small compared with the period of a single cycle of the radio-frequency wave. This was thought to be a fundamental limitation on the generation of high-frequency power since, if the time of flight were a full cycle, any work done by the electrons on the circuit during the first half-cycle would be cancelled by the work done by the circuit on the electrons during the second half-cycle. Electron tubes were designed, then, so that the flight time was negligible compared with a cycle, and this in turn meant that it was necessary to make the tubes smaller and smaller as the intended frequency increased. Because of this limitation, and the necessity of using low-efficiency coil-and-condenser circuits, it appeared that it would be impossible to generate any substantial amount of power at microwave frequencies—not enough, in any case, to be useful for most practical applications.

The fundamental "transit-time" limitation mentioned above was eventually circumvented by a new method of obtaining radio-frequency power in electron tubes. The new development was the result of the discovery of the so-called "velocity modulation" of electron streams, which was due to Heil and Heil in Germany, the Varian brothers at Stanford University, and Hand and Metcalf at

General Electric. Instead of attempting to make the electron flight-time inside the vacuum tube small, the principle of velocity modulation made intentional use of transit times which were very large. To convert a homogeneous electron stream into a pulsating one which could deliver power to a high-frequency circuit, the electrons were made to *bunch* along their path because of the difference in their speeds.

The combination of the principle of velocity modulation of electron beams and the "cavity" resonators of Hansen led to the important development, in 1937–39, of the "klystron" tube, which proved capable of performing, at microwave frequencies, many of the tasks expected of the conventional vacuum tube at lower radio frequencies.

The beginning of World War II accelerated the development of the microwave field by demanding greater power, better detection systems, and a more complete understanding of the various problems associated with the use of microwave methods for radar and communication. Important discoveries in England led to rapid development of the magnetron and eventually permitted this device to deliver a peak power of several million watts at wavelengths in the neighborhood of 10 centimeters.

It is not appropriate to attempt a complete description of the many significant accomplishments in microwave technology during the war. However, it may be of interest to note that the work of the Radiation Laboratory of Massachusetts Institute of Technology eventually led to the publication of a 20-volume series which dealt with the theory and application of microwaves to the radar problem. Because of the importance of the problem, the state of the microwave art advanced a remarkable distance in a short period of five years. Not only were many complicated and successful systems developed, but theoretical understanding of almost all aspects of the field also reached a point of near perfection. The practical devices which emerged from this work were far advanced in nearly every major respect. For example, more peak power could now be obtained at microwave frequencies than had been obtained at the lower radio frequencies; radio receivers could distinguish signals which were only ten times as large as the noise due to natural causes (thermal agitation) in the circuits themselves; theory and design of antennas were highly developed; measurement techniques were perfected to the point where all of the usual electrical quantities could be measured nearly as well as they could be in the radio region, which had been under study for the preceding 50 years; the theory of the behavior of electromagnetic waves in closed regions was highly developed, and the transmission theory could be considered virtually a closed topic except for details of design.

As a result of these war-time developments, it was clearly evident that the future of the microwave field held great promise. Many of the expectations of this period have been fulfilled in post-war developments. Some of the more important of these are described below.

Current Applications

Communications and defense. Perhaps one of the simplest and most direct consequences of the war-time developments is the use of radar for maritime purposes. Today every large ship carries one or more radar sets for the purpose of navigation in bad weather. Although present maritime rules prohibit navigation solely by radar, its use contributes in large measure to the prevention of serious maritime accidents. Maritime radars are designed to indicate the presence of ships, land masses, icebergs, and other objects at distances as far as the horizon. Other types of radar are designed to locate accurately objects close by, and this information is useful in navigation through narrow channels, in harbors, rivers, and in the Great Lakes.

Radar is equally useful in the navigation of aircraft. Although an ideal navigational system has not yet been developed, radars of several types are in constant operation at every major commercial airport; these are used to establish safe traffic patterns by stacking and controlling the aircraft and are also used to assist in landing the aircraft in bad weather. Some modern aircraft also carry airborne radar which permits them to detect adverse weather conditions which are not suitable for convenient or safe flight.

One of the principal present uses of microwaves is in providing a means of communication where a broad frequency bandwidth, on the order of several megacycles, is required. This bandwidth is necessary for rapid transmission of signals which contain a large amount of information, television being an important example. In the United States today, every major city can now receive television programs which originate anywhere else in the United States. This is accomplished by transmitting microwave power over short distances, say 20 miles, and repeating the transmission to cover longer distances. Many countries in Europe and elsewhere have similar networks of "repeater" transmitters either in operation or in development. Some of these countries are also developing similar relay networks to augment or replace the older wire systems of telephone communication. In many parts of the world, microwave methods provide the only practical form of communication. In addition, the recently developed form of microwave relay communication which uses the method of scatter-reflection from the atmosphere makes possible relatively long-distance communication; and this provides means of communication in those sections of the world where closely spaced relay links are either impractical or unnecessary.

The applications of microwaves in defense systems are both numerous and important. Microwave applications are found in nearly every branch of the military service and are used for radar, communication, and navigation, and for the launching, guidance, and fusing of missiles. Some of the defense projects which use microwave techniques have reached very large proportions as, for example, the DEW radar line being built jointly by Canada and the United States.

Science and industry. Just as spectroscopy studies of the emission and absorption of visible radiation have led to an understanding of atomic structure, microwave spectroscopy studies have brought about a more complete understanding of molecular structure. A number of potential applications of great importance have come from this work. An example of these is the development of the "atomic clocks." In one of these atomic clocks, use is made of the spectral line associated with the characteristic inversion frequency of an ammonia molecule. This line, located conveniently at 23,870 megacycles, is extremely stable and is therefore useful as a frequency standard. This spectral line can be observed either by finding the center of the absorption band or, alternatively, by the recent discovery of "induced emission" in a device called the "maser," which will be described in greater detail later. By using one of these methods, it is possible to construct a device which will produce microwave signals whose frequency can be made considerably more stable than the frequency of any other man-made source. By reducing the frequency by conventional electronic methods to the neighborhood of 1000 cycles,

it is possible to use this frequency to operate an ordinary clock. The time derived from an atomic clock by such methods promises to provide a new standard of time, which will be independent of the fluctuations which are known to occur in the present standard, the rotational frequency of the earth. If atomic clocks can be made to attain the precision which present experience indicates is possible, many important discoveries and practical developments should result. In the field of science, for example, it should be possible to repeat the famous but inconclusive experiment of Michelson and Morley to more accurately ascertain whether ether drift does not, in fact, exist. Another application is the possibility of devising completely laboratory-contained experiments to test the theory of relativity.

One of the possible practical applications of extremely stable frequency sources is that of devising new types of navigational systems for use in the air and at sea, and possibly—should the need arise—in the space beyond the earth. If a radio transmitter and receiver, with oscillators operating at precisely the same frequency, are located, respectively, at a fixed station and on a moving vehicle, then the motion of the vehicle will result in the received signal being Doppler-shifted. By comparing the received signal with one generated in the vehicle, the velocity of the vehicle can be determined simply by measuring the frequency difference; and the vehicle's position can be found by integration of the Doppler frequency—that is, by counting the cycles of the frequency difference during the time elapsed. Stability of an oscillator on the order of one part in 10^{10} should result in the determination of vehicle velocity to an accuracy of 1/20 mile an hour. Such stability in atomic clocks does not seem impossible, and is in fact already being approached by some of the devices now being tested.

The ammonia maser can also be used as an amplifier of weak signals. Since it does not use charged electric particles in the process of amplification, the usual noise-generating mechanism in receiver circuits is not present, and this, in principle, makes it feasible to build "perfect receivers"—that is, receivers which can identify electrical signals which are just slightly larger than the natural noise existing in space. This goal has been the object of extensive research at all radio frequencies, including the microwave region; however, at microwave frequencies the known methods of detection and amplification have always resulted in the introduction of noise by the detector or the amplifier to the extent that it has been impossible to detect signals which were weaker than approximately ten times that of the natural noise. It has already been demonstrated that the ammonia maser can bring about a significant improvement in the quality of microwave receivers, and these discoveries have stimulated reseach along related lines.

Another application of microwave power is its use in accelerating particles to very high energies. High-energy electrons, for example, are useful for many purposes: in the range of a few million volts, they may be used for sterilization of food, drugs, and other products and for inducing chemical reactions not otherwise easily produced; in the energy region from a few to 20 or 30 million volts, they are useful for generation of x-rays for industrial radiography and for cancer therapy; in the energy region above this, extending into the multi-billion-volt range, electrons are useful as an important tool of nuclear research. In each one of these applications, microwave methods of accelerating particles are convenient and practical, and in some cases represent the only known method of attaining the desired result. The state of contemporary microwave practice is sufficiently advanced in these fields so that no fundamentally new research is required. What is necessary, of course, is the investment of large sums of money for development and construction of appropriate machines.

Still other applications of microwave radiation may be mentioned. Radio-frequency heating has been a standard technique available to industry, and it is not surprising that microwave power should also find application for this purpose as well. Generally speaking, the methods of generating microwave power are not as efficient as those used to generate the lower radio frequencies. Therefore, microwaves are used for heating purposes only when there is some specific advantage to be gained at shorter wavelengths. A few of the applications in which this is the case are the following. Molding of certain plastic materials can be conveniently carried out by introducing microwave power into the molding-machine cylinders just prior to extrusion. Also, powdered plastic material which is contained in a metallic cylinder can be made to be a resonant microwave circuit and will therefore absorb microwave power readily and rapidly. This process lends itself to mass production of plastic products. A third application, based on the same principle, is the microwave kitchen range. In this application, many kinds of food, by virtue of their dielectric properties, can be heated almost instantaneously.

Current Problems

As has been noted above, microwave research is oriented toward applications in other fields of science and toward industrial applications, and it has led to many important advances. We now turn our attention to some of the central problems which presently concern workers in the field, and also consider further possible applications which might arise. It should be noted here that the following observations do not include activities which are basically a refinement or an extension of known principles, although such work is, of course, very important; it would not be possible to provide a comprehensive description of even the most significant of these activities. The problems considered below are arbitrarily confined to those which involve the search for new principles, new methods, and new applications.

The following general areas of the microwave field are now receiving or can usefully receive attention as topics of research. The general topics listed, and some current approaches to these, are described below in greater detail.

Extension to higher frequencies. In the mid-1930's it was important to find practical means of generating microwave power; one of the central problems at the present time is to find methods of generating radiation in the frequency region beyond that now usable—in the millimeter and submillimeter range. As with the earlier work, there are specific and general reasons for this interest. Among the specific reasons are those which concern the use of short wavelengths in the field of molecular spectroscopy, and also the further extension of the usable frequency spectrum for the continuously growing needs of the communication industry. The general reason, which is the one that fundamentally motivates all new microwave research, is that no one can now predict (just as no one could have predicted the multifarious applications of radio and microwaves) what future applications and discoveries the availability of this broad new spectrum will lead to. It is of very great interest to find methods of generating radio-frequency power in the region between radio waves, on the one hand,

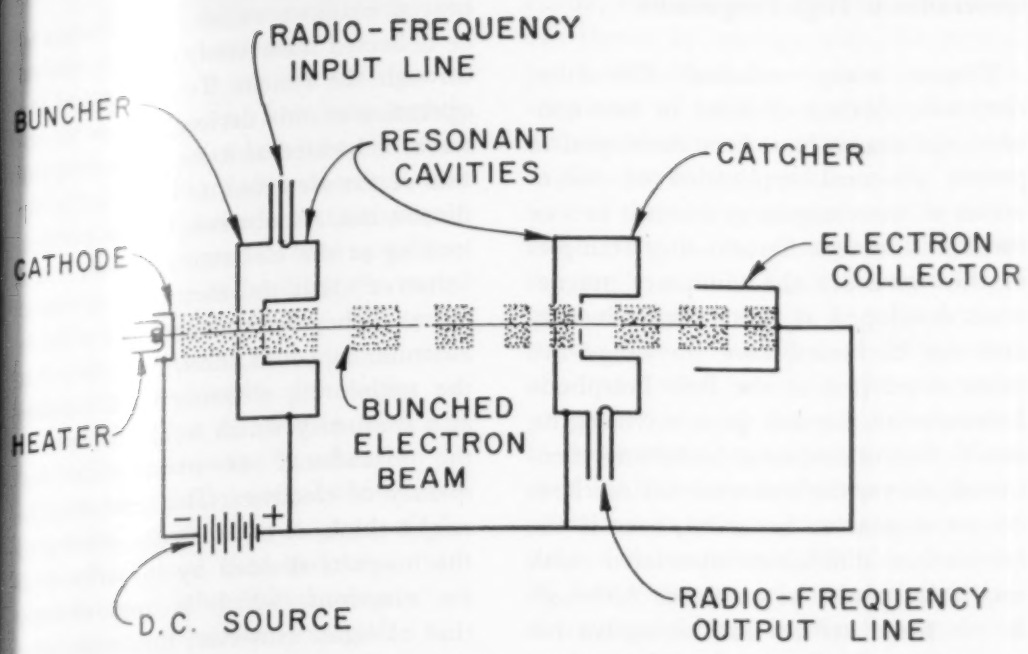

Fig. 1. Essentials of a klystron tube. Electrons emitted from a cathode are accelerated and focused into an "electron beam." The electrons, in passing through the "buncher" cavity, experience time-varying forces due to the radio-frequency fields there. The resultant motion of electrons creates bunches of electrons, approximately as shown. These create pulsating forces in the "catcher" resonator and thus induce amplified signals which can be removed by a coupled output transmission line.

and infrared radiation on the other. An immediate objective of research in this field is to find new methods which will increase the available spectrum by another factor of ten, reaching perhaps down to a wavelength of 0.1 millimeter.

These objectives cannot be reached by simple extension of present electronic methods of generating radio-frequency signals. All present known electronic devices have a fundamental high-frequency limit above which they cannot be made to work. The details of these limitations are complicated, but some insight into the main reasons can be quite readily attained. As the wavelength at which one is interested in building a microwave generator is made shorter, the physical size of the device is necessarily made smaller in proportion. All microwave devices require the use of cavities or circuits whose dimensions are related to the operating wavelength. It also happens that in all electronic devices there is a critical amount of electronic current which must be made available in order to permit operation. If the available current is less than this critical amount, operation of the device becomes impossible, because the power that can be generated by this current is not sufficient to supply the heating losses in the circuits of the device. But as the wavelength of the device is made smaller, the region through which the electron current must pass is also made smaller. This means that the higher the frequency, the lower is the available current, and this is further complicated by the fact that, in general, the required current becomes higher. This situation can be made clearer by considering a specific situation—for example, a klystron, the simplest of all microwave devices. Figure 1 is a schematic diagram of a klystron, in which an electron beam is produced by accelerating electrons from a cathode and focusing them into a cylindrical beam. Along this beam there are a number of resonant cavities, the first of which permits variation of the electron velocity, due to the radio-frequency voltage across its opposite poles. Subsequently, because of the velocity variation, the electrons group themselves in bunches and are able to impart their kinetic energy to the potential energy of the last resonator. The exact process of generation of microwave power is not important for this discussion, but it is important to note three things: (i) As the wavelength is made shorter, all of the dimensions in Fig. 1 need to be reduced in proportion to the wavelength; (ii) as a result, the amount of current available from the cathode is reduced in proportion to the area of the cathode—that is, is reduced as the square of the wavelength; (iii) the losses in the conductors of the resonant cavities become higher. Thus, as the wavelength is made shorter, the available current is smaller, although the required current is greater. At some specific wavelength, therefore, a device of this sort will cease to work. A more careful analysis of this problem demonstrates that a klystron cannot be made to work at wavelengths appreciably shorter than a few millimeters. For other types of microwave generators, such as the magnetron and the traveling-wave tube, the differences in the final result are surprisingly small, in spite of the substantial difference in the method of operation and the configuration of the various devices.

As a result, it has been clear for some time that higher frequencies cannot be attained by application of presently known electronic principles. Several systematic searches for other possibilities have not yet revealed any plausible approach to the problem. The workers in the field have therefore a new challenge: to find a solution to a seemingly hopeless problem. The situation today in this field is similar to that in the mid-1930's, when methods of microwave generation were unknown. The present picture is not completely pessimistic; some suggestions are being explored along lines which will be described in a later part of this article.

Generation of higher power. For several possible applications it would be desirable to provide even greater power than has been attainable before. Either higher peak power, or higher average power, or both, are of interest. The question of increasing the average power is important, for example, in applications involving industrial heating, television and radio transmitters, and so on. In other applications, such as radar and particle accelerators, it is often of interest to be able to generate higher peak power.

In addition to the question of the power level, another requirement of primary importance in many transmitting systems is the ability of the transmitter to respond to large frequency bandwidth —that is, the range of frequencies which a transmitter is capable of amplifying simultaneously. Questions of this type are especially important in radar applications, and the search for methods of amplifying large bandwidths at high power levels represents one of the most important problems in this field.

Detection and amplification of weak signals. Detection and amplification of weak signals is clearly as important as generation and transmission of higher power. At the present time the principal effort to improve the ability of microwave receivers to respond to weak signals has been devoted to studies of traveling-wave tubes, although the results of this work are applicable to other microwave devices as well. However, because the traveling-wave tube, in common with all electronic devices, uses charged particles, the noise generated in the tube by

the electron stream is not negligible, despite efforts to minimize such noise. When the present performance in this field is compared with radio standards, traveling-wave tube operation seems nearly as good as one can expect. But the recent invention of the maser has shown that amplification can be obtained without the use of charged particles. This has led to new possibilities for reduction of noise in detecting and amplifying systems, and these will, without question, be of great importance in the future.

Other applications. The general areas of interest for further research have been stated in terms of microwave applications which are either known today or are possible if certain specific microwave objectives can be attained. It is probable, of course, that still other applications of microwaves will be found. The search for new ideas, new applications, and new methods will continue to be as important as it has been in the past.

There are two areas which seem to provide exceptionally great opportunities for research at the present time. One of these concerns the extension of principles introduced by the invention of the maser: the applications arising from microwave signals which are obtained from systems that do not use electron beams. The second area of speculative interest is the study of possible applications of plasma phenomena in microwave systems—that is, gaseous media in which all or nearly all atoms are ionized. Nearly all radio-frequency generating devices employ electrons exclusively; in retrospect, this seems like an artificial restriction upon the potentialities of electronic devices. That plasma applications have received only limited attention, to date, is due to the fact that plasma phenomena are extremely complicated. The possible importance of this subject, however, is great.

Generation of High Frequencies

Despite many technical difficulties, electronic devices of more or less conventional design have been developed to permit practical application of microwaves at wavelengths as short as two or three millimeters. Outstanding examples of this work are the miniature magnetrons developed at Columbia University and the backward-wave traveling-wave tubes developed at the Bell Telephone Laboratories. Beyond these wavelengths, due to the fundamental limitations mentioned above, the conventional methods do not appear to be useful, even if the fabrication difficulties associated with small size could be resolved. Although as yet there are no obvious means for overcoming this limitation, there are several approaches to the problem now being pursued. It is too early to judge their possible success, but a description may serve as a good example of the work being done in this field.

In one approach, an attempt is being made to obtain microwave radiation from high-energy ("relativistic") electrons by subjecting them to periodic forces. Experiments which use relativistic electrons are currently being conducted by Motz at Oxford University, Coleman at the University of Illinois, and Mallory at Stanford University.

For the sake of illustration, consider an example of one such device, the "undulator" described by Motz and shown in Fig. 2. The electrons are emitted from a cathode (not shown in the illustration) and are accelerated to a velocity closely approaching that of light; this can be readily accomplished by the use of a microwave linear electron accelerator, the understanding of which is again not essential for the present purpose. In the undulator shown, the electrons are made to pass between the poles of the magnets, which are arranged as indicated in Fig. 2. The presence of the periodically spaced magnets causes the electrons to be deflected transversely and to undulate through the system. To understand the operation of this device, suppose an observer is located at some point along the axis of the electrons, as indicated in the illustration. An observer in this position, looking at the electrons head-on, would "observe" that the electrons are vibrating as if they were a current in a dipole antenna; he would, therefore, expect that the undulating electrons would radiate at a frequency which would be equal to the vibrational or undulational frequency of electrons. This frequency, he might think, is equal to the spacing of the magnets divided by the velocity of the electrons, which is approximately that of light. However, this expectation must be corrected because of two factors. Since the electrons are traveling virtually at the speed of light, relativistic effects must be taken into account, and this can be done by assuming that the spacing between the magnets is reduced. Thus, the electrons radiate at a frequency higher than would be expected if relativistic effects were neglected. Further, the electrons are moving toward the observer, and therefore the radiation from the electrons is Doppler-shifted. These two effects, taken together, result in radiation from the electrons (accelerated to a few million volts and with magnet spacing of a few centimeters) in the millimeter and submillimeter range. Experiments of this sort were first done by Motz, who used the linear electron accelerators available at Stanford University; these experiments have in fact shown that the principle can be used to produce electromagnetic radiation which completely bridges the gap between the radio region and the region of visible light.

The principal question that arises in examining the performance of the undulator is that of what intensity can be expected from it. Analysis shows that the behavior of the undulator is very strongly affected by the manner in which the electrons are injected. If the electrons can be sufficiently "bunched" by the linear accelerator prior to injection, so that the longitudinal length of a given bunch is approximately equal to the wavelength which one is interested in generating, the radiation process can become quite efficient. This is due to the fact that all the electrons in the bunch would radiate "together"—that is, radiation from each electron would reinforce radiation from the others. The practical problem is, therefore, to cause the electrons to bunch very tightly; this happens

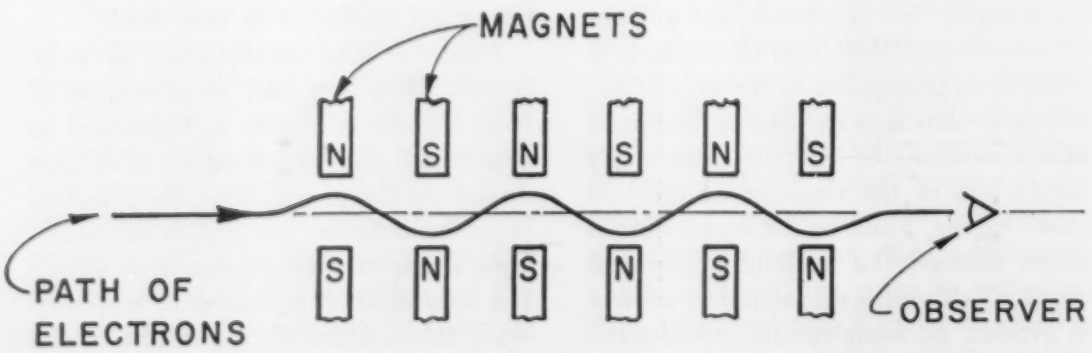

Fig. 2. Elements of the Motz undulator. Electrons arrive in bunches from the left, from a linear electron accelerator, and are forced to execute periodic vibrations due to the forces exerted by the magnets. The observer (with the aid of suitable detectors) at the right will find electromagnetic radiation of a higher frequency than the microwave frequency in the linear accelerator.

to be a difficult problem and is the central one of current research.

The undulator is not the only means for extracting power from the tightly bunched stream of relativistic electrons. Mallory, at Stanford, has observed that injection of a bunched electron stream into a hollow metallic tube produces radiation in the submillimeter range without the employment of any transverse undulation. This phenomenon, which is believed to be due to the extraction of higher harmonics from the bunched beam, seems to be related to the behavior of ordinary nonrelativistic frequency-multipliers. The success of devices other than the undulator also depends upon the initial degree of bunching which can be obtained.

The use of relativistic electrons cannot lead to development of simple, small, inexpensive sources of laboratory power, since this requires a powerful microwave source and a means for accelerating electrons into the relativistic region. Even so, the successful development of these devices would stimulate further experimentation and development and should eventually result in new approaches to the problem.

A different approach is currently being pursued by Linhart of the Comité Européen de Recherche Nucléaire (CERN) in Geneva. Linhart intends to use plasma phenomena in a novel way. His idea can be understood by considering a mechanical analog, as shown in Fig. 3. A weight is suspended by a string which passes over a support, and this can be adjusted to shorten the length of the pendulum or "oscillator." It is well known that the work done by the force F will cause the swinging pendulum to oscillate at an increased frequency, as the string is shortened, provided that the fractional decrease in the length of the string is small during a single cycle of oscillation. According to a well-known theorem, if this "adiabatic" criterion is obeyed, the internal energy of the oscillator will be proportional to its frequency. In principle, this can be applied to the microwave case in a manner shown in Fig. 4. Suppose a microwave cavity, which can be tuned by a moving plunger, is excited at some specific position of the tuning plunger by a source of microwave power until steady-state resonance conditions are established. If the power were then turned off suddenly, the fields in the cavity would attenuate exponentially with time. If, however, during a period of time which is short compared with the decay time, the plunger is moved rapidly downwards to reduce the volume of the cavity, then the work done on the cavity (as shown by analogy with the pendulum) will result in an increase of the frequency of oscillation and in the generation of electromagnetic energy. (As in the case of the pendulum, the reduction of the cavity volume must be adiabatic—that is, the change in length of the cavity must be small during a single cycle of oscillation.) It is easily demonstrated that the mechanical deformation of a microwave cavity by this process is completely out of the question because of the extreme velocities needed. However, Linhart suggests the use of a plasma phenomenon which seems to have the proper characteristics for the problem. He believes that a column of plasma (indicated graphically in Fig. 5), produced by ionization of some suitable gas by a second electron stream, can be excited as an electrical resonator and would have very low losses. (This suggestion is believed to be due originally to Fainberg of the U.S.S.R.) If the electrons of the plasma column are suddenly accelerated, the resulting electron current creates a magnetic field around the plasma which causes the electrons to converge radially, or to "pinch." During this pinch, the inward motion of the electrons produces the desired rapid decrease of size of the plasma resonator and should result in the phenomena described above in terms of the mechanical tuning of the cavity. Research along these lines is currently being pursued by Linhart and his associates.

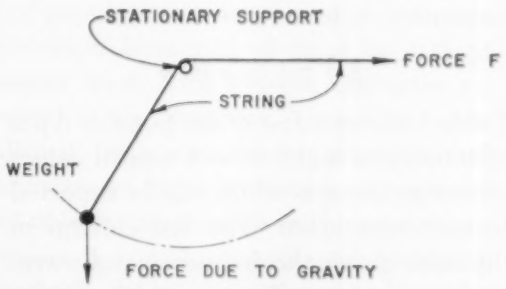

Fig. 3. A pendulum which, by shortening of its length, demonstrates the adiabatic principle of frequency multiplication.

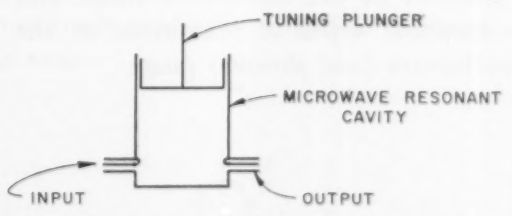

Fig. 4. Application of pendulum principle to a microwave case; the motion of the tuning plunger compresses the stored energy and increases the frequency of oscillations.

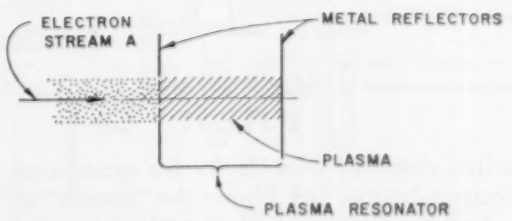

Fig. 5. The use of plasma as a microwave resonator.

Still other ideas which make use of plasma phenomena are being considered by workers in several countries; these are all speculative, since the characteristics of plasmas are still only partially understood.

Novel Methods of Amplification

In all conventional amplifying devices, including the triode, the klystron, the traveling-wave tube, and others, direct-current power is converted to radio-frequency power by first accelerating electrons from rest and then removing a part of the kinetic energy of the electron stream by exposing the electrons to radio-frequency fields in the output section of the amplifying device. Although this basic process can be executed in a number of useful ways, all of these have certain fundamental limitations, as previously mentioned. Two of the basic difficulties encountered with all electron devices are as follows: (i) Even in the absence of an input signal, all electronic devices produce an output, which is usually referred to as "noise." This is due to the fact that charged particles (that is, electrons) induce electrical signals in the output circuits due to random emission from the cathode and random variation in their velocity. (ii) Electrons even at the highest practical voltages have velocities which are not large enough to permit instantaneous interaction with radio-frequency fields; as in the triode, the "transit-time" effects preclude the extension of known techniques above a certain frequency limit.

Electronic devices of this sort are not, of course, the only means of generating electromagnetic energy. The generation of visible light is a familiar example of a process which is considerably different. In this case (to use the terminology of classical physics), electrons in one orbit can be transferred to a higher one by excitation (as in gas discharge), and this will result in emission of light when the electron spontaneously returns to its original orbit. This process demonstrates the principle of conversion of energy (in a gas discharge, from a direct-current source) to electromagnetic form by the use of electrically neutral atoms. In

Table 1. Frequency and wavelength of electromagnetic radiation that can be expected from the various types of atomic, nuclear, and magnetic transitions.

Type of transition	Representative change in energy (electron volts)	Corresponding radiation	
		Frequency (Mcy/sec)	Wavelength (cm)
Atomic-electronic transitions (visible light)	~ 2	6×10^{8}	0.5×10^{-5} (5000 A)
Molecular transitions:			
Vibrational	10^{-3}	2.5×10^{5}	1.2×10^{-1}
Rotational	10^{-4} to 10^{-6}	2.5×10^{4} to 2.5×10^{3}	1.2 to 12
Paramagnetic ions (orientation of)	10^{-4} to 10^{-6}	2.5×10^{4} to 2.5×10^{3}	1.2 to 12
Nuclear moments (orientation of)	$\sim 10^{-7}$	25	1200

terms of contemporary theories, it can be said that a neutral atom can radiate a quantum of energy in undergoing the transition from one allowable energy state (orbit) to another allowable state. It has recently been demonstrated that this principle can also be applied to both the generation and amplification of microwave power. Since this process does not use charged particles, but rather neutral atoms, it is possible to visualize devices which would have the same sources of noise and would considerably increase sensitivity in the detection of weak signals.

To understand the possible application of this principle to the generation and amplification of microwave frequencies, it is first necessary to consider the separation between energy states in molecular, atomic, and nuclear structures. According to quantum theory, the motions of electrons in atoms, of atoms in molecules, and of fundamental particles in nuclei are restricted in a manner which results in discrete energy-state levels (analogous to the classical concept of electron orbits in atoms). The excitation of an atom or a molecule can change its state from one level to another, and radiation of energy will take place upon return to the original state. According to the Einstein equation,

$$\Delta W = h\nu$$

where ΔW is the energy change, h is Planck's contant, and ν is the frequency. If W is measured in electron volts, and ν in megacycles per second, this relation becomes

$$\Delta W = 4.14 \times 10^{-9}\nu$$

Table 1 shows a few of the possible types of transitions together with typical values of energy changes which can be expected in such transitions. The last column in the table shows the frequency and wavelength of the radiation which results from such transitions. From this table it can be seen that rotational molecular transitions can be expected to generate radiation in the microwave range and vibrational types of transitions in the millimeter (and shorter) range.

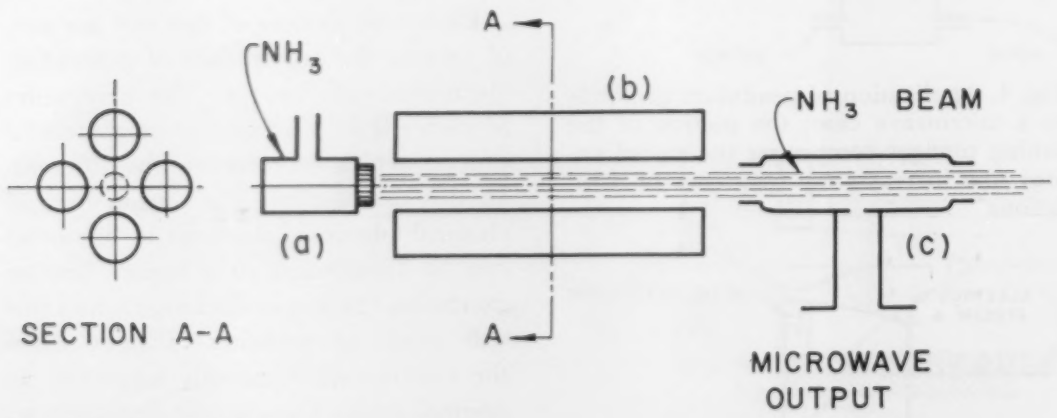

Fig. 6. Schematic diagram illustrating the principle elements of a device for generating or amplifying microwaves without the use of electron beams. (*a*) Shows the "source" of ammonia gas through which the gas diffuses through small tubes; (*b*), the "focusing elements," whose cross section is shown at the left; (*c*), the microwave cavity and the output waveguide.

That emission of radiation from a molecular system is possible does not, in fact, mean that this can be accomplished as simply as generating visible light by excitation of atoms in a gas discharge. To understand this, consider a molecule with two energy states between which transitions can occur. If the molecule is in the lower energy state, it can absorb microwave power and be raised to the high-energy state; if it is in the higher state, it can radiate the energy in the process of transition to the lower state. It turns out that the probability of these processes occurring is the same, and in a body of gas or other material with equal population densities of the two states, the radiation of energy is impossible. In the actual case, with common materials at thermal equilibrium, there is an excess of lower-state molecules, and the medium can only absorb radiation. This fact has been well known and it explains why molecular radiators have not been developed until a short time ago.

Recently, suggestions of Townes at Columbia University and of others have changed this picture. They have demonstrated that it is possible to separate the energy states to provide a region in space where an excess of molecules in the upper state, capable of emission of radiation, can be made to exist. A device of this type, called a "maser," may be of interest since it is the first and still the clearest demonstration of an important new principle. (The word *maser* has been derived from "*m*icrowave *a*mplification by *s*timulated *e*mission of *r*adiation.")

A schematic diagram of the principal elements of the Townes maser is shown in Fig. 6 (the walls of the vacuum chamber which surround the entire apparatus have been omitted). Although any one of a number of gases can be used, Townes selected ammonia for his experiments because the transition frequency occurs in a convenient microwave region, and because the population-density difference in one pair of states happens to be particularly large. Ammonia gas at reduced pressure is introduced into a box, called the "source," from which it diffuses through an array of small tubes to form a molecular beam, as indicated in the diagram. The beam then passes between sets of rods, called the "focuser," in which alternate rods are connected together electrically, with a high electrical potential applied to the adjacent rods from a direct-current source. Although the focuser does not supply any elec-

trical power to the system, it does two things: As the molecules drift between the rods, the presence of the electric field causes the molecules to become polarized in the form of electric dipoles and, as a result of this, causes many of the lower-state molecules to be defocused and removed from the system by outward radial drift. The beam which finally enters the last region of the maser, the microwave cavity, therefore contains an excess of molecules in the upper state and is in the proper condition to radiate this excess energy. If the number of upper-state molecules sufficiently exceeds the number of lower-state molecules, the radiation from the former can create a field in the resonant cavity which can be extracted for use by means of microwave waveguide, as shown in Fig. 6. The frequency of operation of the maser, as built by Townes, is 23,870 megacycles, and this can be shifted by only a small amount by tuning of the cavity or changing of the focusing voltage.

If the ammonia beam current is too low, the device will not oscillate. In this case, however, the maser can be used as an amplifier. Due to the presence of the ammonia current, the losses in the microwave cavity can be made to be negative, and a signal sent into the cavity can be reflected in amplified form. Since the ammonia amplifier does not employ charged electrical particles, there is no noise of the conventional sort induced in the microwave cavity. Recently, measurements by Helmer, at Varian Associates, have shown that the ammonia maser, when used as an amplifier, has only about twice the noise level expected from an "ideal" amplifier.

Although the ammonia maser is potentially very useful as an amplifier, and also as a source of extremely stable microwave frequency, it does have certain characteristics which limit its use in many important applications. The principal difficulties with the maser are as follows. The electrical bandwidth of the maser is very small—in the neighborhood of a few thousand cycles—which limits its application to those cases where the information is narrow-band. Amplification by the ammonia maser occurs at a fixed transition frequency, and the device cannot be "tuned" to other microwave frequencies (except, of course, to other discrete frequencies at which different molecular transitions are possible). Due to the limited current which can be obtained in a molecular beam, the power output of the maser is very low, in the neighborhood of 10^{-9} watt. In many applications of practical importance, one or more of these limitations represent a serious obstacle.

It appears, however, that there are other possible methods which might be used to separate energy states in a medium to create a situation conducive to transitions in the microwave region. For example, it is possible to expose certain solid materials to microwave radiation of one frequency to equalize the population densities of two energy states (one of which at room temperature has very low population density) and to induce a transition from one of these to a third energy level. This process, currently referred to as "pumping," can be accomplished by a number of methods and promises to provide many combinations suitable for application in the microwave region. A combination of such pumping methods, the splitting of energy levels by means of static magnetic fields, and the use of materials with suitable properties represents a field of research of great importance, from which amplifiers of near-maximum sensitivity might be expected to arise.

High Power and Large Bandwidths

Despite the fact that microwave devices have already proved capable of very high power generation over very broad bandwidths, there are still two kinds of reasons for trying to exceed the performance of the presently available devices. The first of these is a specific one: There are a number of immediate applications which can profitably employ higher power or larger bandwidths, or both. For example, in both radio communications and in radar the use of higher power permits communication over a greater distance and with greater reliability; in particle accelerators, higher power produces greater particle energies, and this, in turn, makes possible new experiments in high-energy physics. The second reason is a more general one: In working toward higher power, one finds various difficulties not previously encountered. The study of these difficulties sheds light on the ultimate limits which can be attained and yields information which is useful in improving the performance of devices which operate below the maximum power limits.

Large bandwidth is desirable for a variety of reasons, all related to the fact that it is becoming increasingly necessary to be able to transmit and to receive greater amounts of information in a given time. There are many reasons, too specific and detailed to be listed, which justify the search for greater intelligence-handling capability of both transmitting and receiving systems. In receiver work, extensive research carried out during the last ten years has resulted in design of a number of types of traveling-wave tubes which are either now available or are known to be possible. These tubes typically have bandwidths on the order of

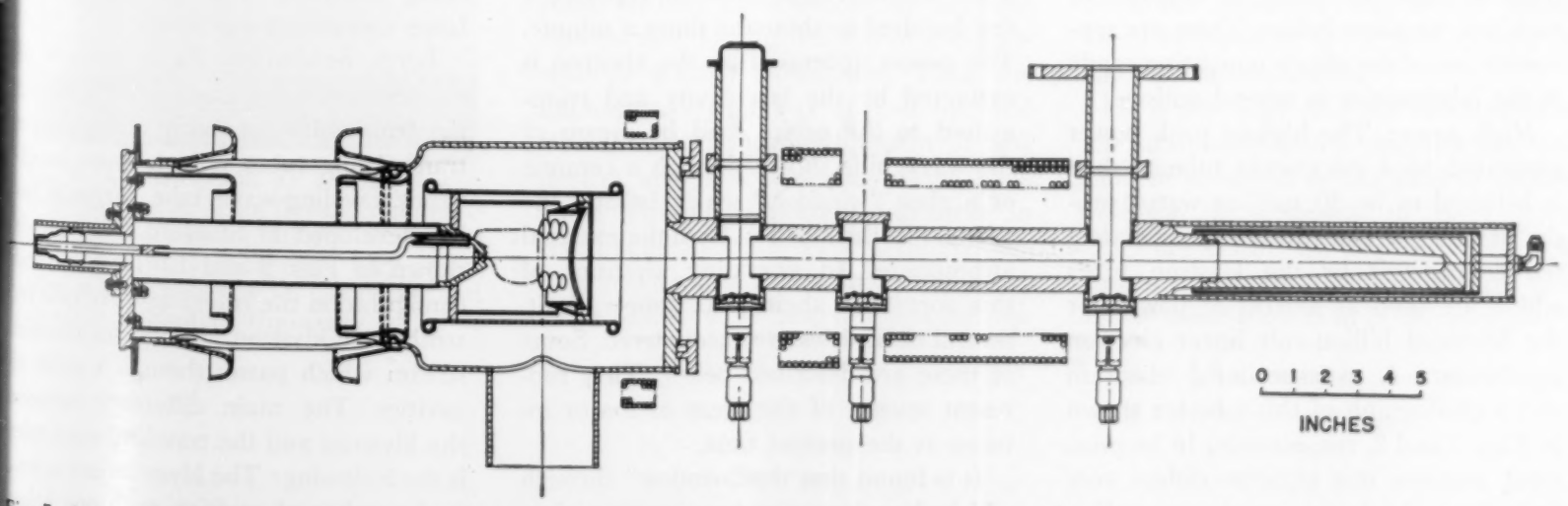

Fig. 7. A cross-sectional diagram of a high-power Stanford klystron. This tube, one of 22 used to power the Stanford "billion volt" linear accelerator, is capable of generating 30 million watts at a wavelength of 10 cm.

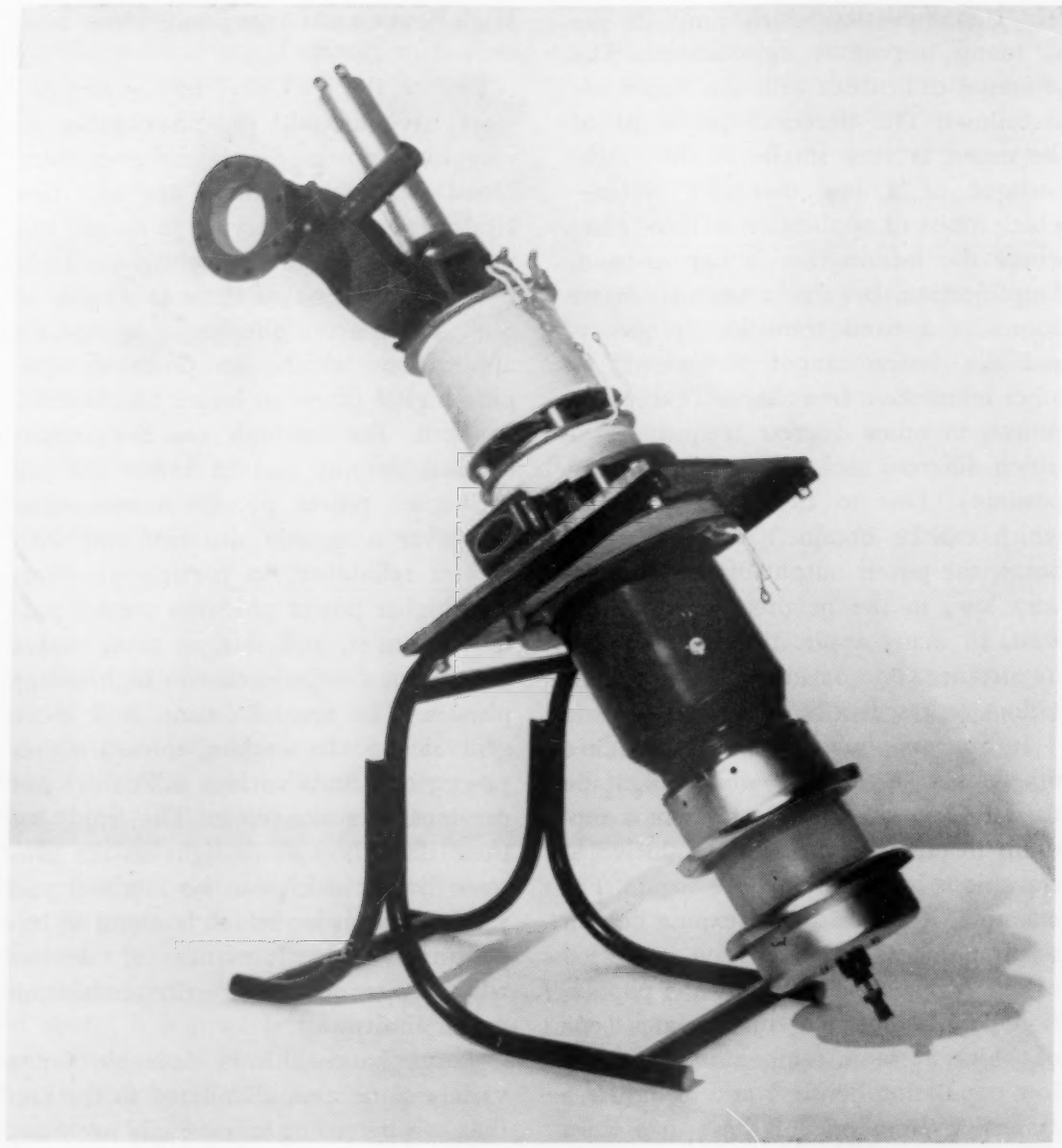

Fig. 8. The high-power Stanford klystron illustrated schematically in Fig. 7.

30 to 50 percent, and nearly the whole microwave spectrum is covered by the series of tubes now available. However, in many applications it is not sufficient to be able to receive information over a large bandwidth, and the problem of generating power over a large bandwidth has many aspects which remain to be solved.

To illustrate the current research activity in these two areas, an example of each will be given below. These are representative of the efforts now being made in the laboratories in several nations.

High power. The highest peak power generated by a microwave tube to date is believed to be 30 million watts, produced at a wavelength of approximately ten centimeters by the klystron tubes which are used as sources of power for the Stanford billion-volt linear electron accelerator. A cross-sectional diagram and a photograph of this tube are shown in Figs. 7 and 8, respectively. In its principal features this klystron differs very little from the basic one shown earlier, in Fig. 1. To generate this power, the klystron used an accelerating potential between the cathode and the anode of approximately 360,000 volts, with an electron current of about 215 amperes. The power input to the klystron, therefore, approaches 80 million watts, not far from the electrical power used continuously by a medium-sized city. This power cannot, of course, be generated continuously but is obtained in pulses of a few microseconds' duration, repeated a few hundred or thousand times a minute. The power generated by the klystron is extracted by the last cavity and transmitted to the useful load by means of the waveguide shown through a ceramic or a glass "window," which isolates the vacuum in the klystron from the external atmosphere. In operating klystrons of this sort near their peak power limit, several difficulties are encountered. Some of these are described below. They represent several of the areas of major interest at the present time.

It is found that the "window" through which the microwave power passes often fails through being punctured (this spoils the vacuum inside the klystron). The processes in these punctures are not as yet clearly understood, although they seem to be related to the unavoidable irradiation the window receives from x-rays and electrons. The work thus involves an attempt to understand the exact mechanism of electrical failures of dielectric materials when subjected to irradiation, and also an attempt to solve the problem by finding materials with greater resistance to such radiation, or by finding practical methods of shielding the windows. A second problem in the operation of present tubes is electrical arcing in the anode-cathode region. Other work is concerned with study of cathode materials which might provide longer tube life and more reliable emission.

The research activity noted above involves, to a large degree, study of the characteristics of materials when subjected to unusual conditions: electrical stress at high frequencies, exposure to x-ray and gamma radiation, and so on. Progress in this field is necessarily slow since it requires the combined skills of chemists, physicists, metallurgists, and engineers, in addition to a long and expensive program of material research and testing.

A more specific microwave problem has to do with the efficiency of conversion of direct-current power to radio-frequency power in microwave tubes. Efficiency of operation becomes increasingly important as power levels increase, since power lost in heat becomes more expensive to consume and to supply. The basic design principles of klystrons, despite many years of experience, are not yet completely worked out because of the complex behavior of electron streams of high density when subjected to magnetic-focusing fields and radio-frequency forces. These complex questions are now being analyzed, with the assistance of large computing machines.

Large bandwidth. As an example of the research being carried out to extend the bandwidth capability of high-power transmitting tubes, a high-power broadband traveling-wave tube currently being developed at Stanford University is shown in Figs. 9 and 10. In its general configuration the traveling-wave tube resembles a klystron, having an electron stream which passes through a series of cavities. The main difference between the klystron and the traveling-wave tube is the following: The klystron uses a limited number of cavities, each one being simply a resonant circuit, and these are

adjusted independently to respond to the frequency which one is trying to generate or amplify. The traveling-wave tube, of the type being discussed, has a number of cavities which are coupled together electrically to form a transmission circuit through which an electromagnetic wave can propagate from one end to the other. As the wave travels through the circuit it exposes the electrons in the beam to relatively weak electric forces, but for a protracted period of time. During this period of exposure, accumulated forces upon the electrons cause them to bunch and eventually to deliver power to the output terminals, much as with a klystron. Because a high degree of resonance is avoided by the use of tightly coupled electrical circuits, the electrical bandwidth of the traveling-wave tube can be many times that of a klystron.

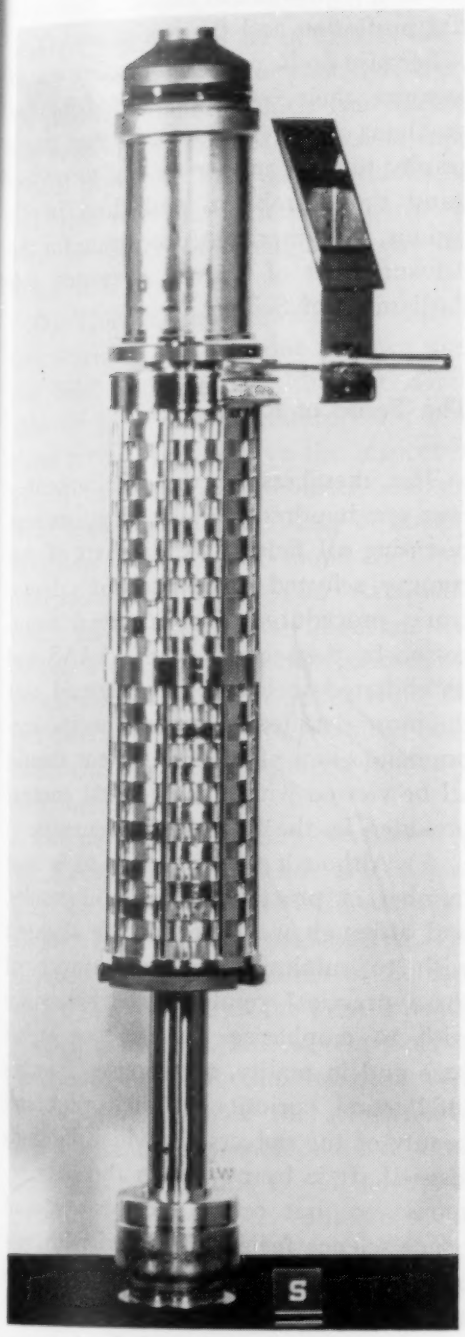

Fig. 9. A photograph of a high-power, broad-band tube. This device, representative of the current efforts to extend the bandwidth of microwave high-power tubes, is being tested by M. Chodorow and associates at Stanford University.

In order to make a satisfactory traveling-wave tube of the kind shown, it is necessary to design the assembly of cavities as if it were an electrical filter, and also to control the propagation velocity of the waves through the structure so that it will match the velocity of the electron stream. It is further necessary to arrange the fields in the cavities so that the electrons are exposed to the highest possible electric fields. These requirements cause the configuration of the cavity structures to become highly complex, so that understanding the behavior of such structures requires extensive experimental work and complicated analysis. Development of adequate theory for these kinds of microwave structures, experimental design of suitable cavity elements, and a great number of other practical problems still remain to be resolved before tubes of this class can be said to be fully understood and ready for practical application.

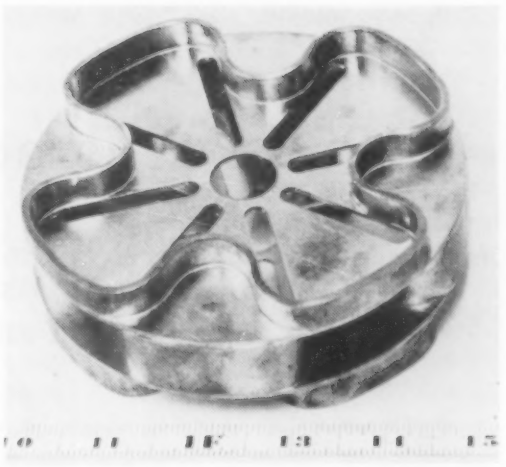

Fig. 10. A section of the "circuit" of the high-power broad-band tube shown in Fig. 9.

Conclusion

It is instructive to consider, in historical perspective, the way in which the microwave region of the electromagnetic spectrum came into use. During the 1930's, the "transit-time" of electrons, associated with conventional radio tubes, and the size requirements of circuit elements appeared to impose a fundamental limitation on the frequencies which could be used. This limitation was overcome by the development of resonant cavities and the formulation of the principle of velocity modulation. Thus, the microwave region was opened up, and with it came rapid development of new devices and new principles which have made possible important advances in communications, navigation, radar, particle accelerators, and a number of other fields which were not foreseen by the workers in the field. In like manner, extension of the usable electromagnetic spectrum into the millimeter and submillimeter region seemed, until recently, to be extremely difficult, if not impossible. With increased insight into such phenomena as molecular transitions, however, this limitation, too, appears now to be artificial. Work in this new field gives promise of developments which will also have great importance. The significance of this historical development seems sufficiently clear: the reservoir of knowledge fed by research almost inevitably flows over into new fields and new applications and provides methods by which still further knowledge may be acquired.

The examples of current research listed in this paper cannot do justice, of course, to the intensive and varied research being pursued in many of the laboratories throughout the world. Not mentioned, for example, is the very important possibility of extending the findings of semiconductor research to the microwave region. Suggestions have already been made which may extend the present high-frequency limit of the conventional transistor and would permit the development of related devices at microwave frequencies.

It is my hope that the description of the accomplishments, applications, and current problems in this field of applied research is sufficient to demonstrate that the future of this work holds as much promise as it held for the pioneers of the microwave field in the mid-1930's.

1958 Parliament of Science

Conducted in Washington, D.C., 15–17 March by the AAAS, it offered these recommendations on education and the support of science

The power of man through science is currently assuming a new order of magnitude. Power has always been sought avidly. Sometimes it has been used disastrously; often it has been used wisely. How the United States shall keep abreast of the developments in science and scientific technology; how it shall help avoid disaster; how it shall ensure that new knowledge (the age-old synonym for power) will be used for the benefit of mankind in general and its citizens in particular are among the most important questions before the American public today.

But the American public is disturbed, worried, and confused. We thought we were well in the lead, scientifically and technologically. Now, all of a sudden, this comfortable assumption is challenged. We are "behind." It isn't clear just what this statement means, or whether the serious versions of its possible meanings are in fact true. But there is no denying the general concern, and the almost frantic determination to "do something about it."

The concern and the determination are, we believe, justified. But it is imperative that we sort out our ideas, brush off as superficial certain spectacular but minor items, and try to see our problem in its true dimensions.

Not long after the discovery of fission, we began to sense the fact that man's impending control of atomic and nuclear power made possible, and indeed made inevitable, the beginning of a new age. As the still more vast potentialities of fusion were made available for destructive purposes, and as it became clear that these incredible forces would presently be tamed for nonmilitary use, the magnitude of our break with the past became visibly greater and greater.

We are just beginning to see that even these advances, tremendous as they are, constitute the signal, rather than the substance, of what is to come. Our successful probing into the nucleus of the atom is but an example of the clear fact that science is entering a new and accelerated stage of advancement, which will give to man the possibility of control over his environment, over himself, and over his destiny, which we have as yet only vaguely sensed. With prospects that are —just as they were in the case of nuclear energy—both marvelous and frightening, we are on the threshold of an equally revolutionary probing of the cell and of the mind.

Man is breaking with the past, its limitations and its safeguards. The prize is greater than ever before—so are the risks. The question is not, "Do we like this?" The question is, "What role do the people of the United States wish to play in the drama of the future?" We cannot hide. We must not relax. How can we play a noble part?

What concerns us here is far and away larger than any question about a satellite, or even about a battery of long-range guided missiles, although these dramatic devices have precipitated discussion and have produced a readiness to consider drastic action.

We are in fact saying that man is on the very edge of a new relation to the atom, to the cell, to himself, and to the universe in which he is set. Many forces have been active, but clearly it is science which has been chiefly instrumental in bringing about this new relation. The new relation will place new demands on all man's resources—especially on his capacity to handle this new power with wisdom, restraint, and decency.

This scientific revolution will totally dwarf the Industrial Revolution and the other historical instances of great social change. It will be more compelling, and will pose more urgent problems, because of both the pace and the magnitude of the changes which now impend.

What faces man is not, in any restricted sense, a scientific problem. The problem is one of the relation of science to public policy. Scientific issues are vitally and almost universally involved. The special knowledge of the scientist is necessary, to be sure; but that knowledge would be powerless or dangerous if it did not include all areas of science and if it were not effectively pooled with the contributions of humanists, statesmen, and philosophers and brought to the service of all segments of society.

What is to be done? Scientists certainly have no arrogant illusion that they have the answers. But they do want to help. They are, moreover, convinced that the time is overripe for a more understanding collaboration between their special profession and the rest of society.

Because it is urgent for scientists to organize their own thinking about the problems raised in the preceding paragraphs, and urgent for society to understand those problems and their implications, the American Association for the Advancement of Science convened this Parliament of Science.

The Terms of Reference

The members of this Parliament—over one hundred working scientists representing all fields and all parts of our country, selected as the result of a democratic procedure which involved nomination by the sections of the AAAS and its affiliated societies—have agreed that the more detailed and more specific recommendations of the Parliament should all be viewed within the general context provided by the following statements:

A) Although science leads to a vast number of practical and useful results, and although we have not the slightest wish to minimize the importance of these practical results, nevertheless we wish to emphasize that science is, at base and in reality, a response of man's intellectual curiosity to the order and beauty of the universe in which he finds himself. It is by no means the only response to that order and beauty, and hence science feels itself allied with, not opposed to, such other responses as the arts and humanistic studies.

B) The pursuit of knowledge is an activity of the human race, not an activity of political subdivisions. As citizens we recognize that the hard realities of the present world sometimes require, or at least seem to require, certain restrictions on the complete international freedom of basic research. But we earnestly think that these restrictions are often wrong and futile. Furthermore, we wish to place a special, positive emphasis upon the kinds of scientific problems—the kinds

of international cooperation in science—which capitalize upon our universal common interests as members of the human race, such as our common struggle against disease and hunger. Scientists of all nations are engaged in a common enterprise. They are urged to take leadership in international understanding and thus to make progress toward permanent peace.

C) Many of the important—and especially the broad—questions concerning science and society do not usefully permit categorical or permanent answers. It is therefore not to be expected that our answers will always be a firm or fixed "yes" or "no." It is essential that there be flexibility within which can operate the evolving human judgments on individual problems, and within which can be preserved the variety which is so great a source of strength in our national life.

D) The statements which a competent scientist makes about his own special field are based upon the facts available to him and his interpretation of those facts. They deserve the respect of society as scientific statements, and deserve also the understanding of society that new facts may be found and new interpretations made. The statements which any scientist makes about matters outside his field of scientific competence should neither gain nor suffer from the fact that the author is a scientist. Such statements should be judged on their own merits.

The problems that were considered at this Parliament of Science are in part scientific and in part they depend on a wide variety of other considerations. The members of the Parliament of Science were trying to serve in the joint capacity of scientist-citizens, and were trying, in the case of each individual question considered, to illuminate the scientific issues as much as possible with a minimum of confusion due to our inevitable, and we think proper, differences of opinion on the social issues.

E) Not only does each answer to a scientific question characteristically lead to a series of new scientific questions, but scientific advances—as we are all aware these days—also give new and difficult form to certain problems in the social, political, and moral fields. It is futile to suppose that society can avoid these problems. As scientists we are concerned with the discovery of new truth. As scientist-citizens we are concerned that the power which this new truth brings be used wisely and decently for the welfare of humanity as a whole.

> The Board of Directors of the American Association for the Advancement of Science, in session on the day following conclusion of the Parliament of Science, voted to express its satisfaction with the Parliament as a method of expressing the collective judgment of a representative group of scientists on matters of public policy, and to commend the recommendations of the Parliament to the attention of all scientists.

F) The strengths and the weaknesses of our scientific and educational systems reflect strengths and weaknesses existing in our political and social environment. The way science is used depends upon the values of the community. The climate of opinion about intellectual activities influences the progress of science, the uses of science, and the kind of people who enter science.

G) The freedom we cherish is served and strengthened by science. Science must also share in this freedom. In the long run it is not possible to have vigorous and imaginative science unless society is willing to provide a total climate, within which scientists work, which assures freedom of choice of problems, freedom to travel, freedom to communicate, freedom to disagree. There appear to be no qualifications to the choice here posed: a full intellectual freedom for scientists, or a weak and declining science.

H) Although this Parliament of Science quite properly concentrated on problems of science and public policy, and although some of the recommendations are quite specific to science, it must be emphasized that science represents only one part of intellectual endeavor. Both public policy and the welfare of science require an educational system that is strong at all levels and in all fields of knowledge. Efforts to advance science at the expense of other fields of learning would harm all fields of learning and the society they serve.

Reports on Specific Topics

The Parliament of Science addressed itself to five main topics:

I. *The Support of Science.* Discussion leader, William V. Houston, president, Rice Institute. Recorder, Mina S. Rees, dean, Hunter College.

II. *Organization and Administration of Science in Government.* Discussion leader, W. Albert Noyes, Jr., dean, Graduate School, University of Rochester. Recorder, E. R. Piore, director of research, International Business Machines Corporation.

III. *Communication among Scientists and Communication of Scientific Ideas.* Discussion leader, J. Murray Luck, professor of biochemistry, Stanford University. Recorder, Mary I. Bunting, dean, Douglass College, Rutgers University.

IV. *The Selection, Guidance, and Assistance of Students.* Discussion leader, Henry Eyring, dean, Graduate School, University of Utah. Recorder, Harry C. Kelly, assistant director, National Science Foundation.

V. *The Improvement of Teaching and Education.* Discussion leader, George W. Beadle, chairman, Division of Biology, California Institute of Technology. Recorder, James F. Crow, professor of zoology and genetics, University of Wisconsin.

In addition to over one hundred scientists who attended the conference, a number of representatives of other professions, and activities (politics, business, law, religion, labor, mass media of communication, other academic professions, etc.) were invited to attend as regular working members of the meeting. The scientists particularly appreciate the interest of those who accepted the latter type of invitation. Although the public representation was not as large as had been hoped for, it was most encouraging and helpful.

Over sixty accredited observers, representing a wide variety of academic, industrial, governmental, and other research agencies, attended the sessions and contributed greatly by their presence and by their participation in the informal parts of the discussions.

After an opening, general session, the groups considering the five topics listed above met separately in at least two extended sessions. Their reports were then brought before two successive sessions of the entire Parliament. Since the five groups worked quite separately, their individual reports took somewhat different form. It has seemed neither necessary nor useful to bring them to a uniform format.

Reports of the five discussion groups were presented to the entire Parliament in an afternoon session on the second day and were voted on in a concluding session on the third day. Few votes were unanimous, but few departed greatly from unanimity. Items on which the vote was substantially split are identified, and the vote is given, in the following sections, each of which reports the recommenda-

tions of the Parliament on one of the five general topics considered. Some of the recommendations are addressed to scientists themselves; others are addressed to the Federal Government, to fund-granting agencies, to the press, or to the public.

Report of Section I, The Support of Science

The well-being of man, his health, and his security depend now as never before upon science, and society recognizes the value of science by these tangible results. If these useful results are to continue, it is imperative that science have a strong foundation of basic research, the untrammeled exploration of the universe and of man in the universe. If basic research is encouraged to grow steadily and healthily, useful results will inevitably follow.

Research must be supported in two ways: first, by general recognition that learning—all learning—is a high calling, to be respected; second, by money. But simply more money is not enough. Funds must be provided under conditions that encourage and support creativity. Support for basic research in universities must be provided in ways that maintain a system of diverse and free institutions and in ways that maintain within universities a balance between the research function and the interlocking teaching function. Universities should be models of freedom in our society where free inquiry and free expression in the arts and the humanities, as well as in the sciences, can go forward.

These objectives can be most effectively sought through a mixed private-governmental system of support designed to bring the diverse judgments of large numbers of wise people to bear on a continuing series of difficult and significant problems.

The main sources for the support of basic research are government, industry, foundations, and universities. Whatever the source of support for research in universities, it is important that this support be given in such a way as to (i) maintain the institution's autonomy; (ii) give freedom to the research worker to choose his own area of research, and provide flexibility to enable him to move from one problem to another as his results warrant or his interests shift; (iii) provide continuity, stability, and other conditions that enable research men to devote their time and energy to research.

(*Note*: The following recommendations apply particularly to universities. This emphasis resulted from the necessity of confining discussions to manageable scope; participants were well aware that much research is carried out in industry, government laboratories, museums, biological research stations, and other agencies that are not connected with universities, but did not have time to consider adequately the special problems of support of research in these agencies.)

Recommendations. 1) Science should be supported on a greatly expanded scale. In using these increased funds, science-supporting agencies, scientific societies, government and industrial laboratories, and universities are urged to find ways of recognizing and encouraging exceptional creative ability and significant productivity.

2) To attain a more productive balance among fields of science in this country, additional funds for large and expensive research undertakings in the biological and social sciences are imperative. Only in this way can the full opportunities arising from the balanced growth of science be realized.

We take particular note that one result of some recent applications of science has been the creation of hazards to human welfare which we are not yet able to understand or control, with the consequence that we are now handicapped by our ignorance concerning many biological questions which have taken on great urgency. Certain studies—for example, large-scale investigation of biological processes in controlled environments such as the genetic and pathological effects of long-continued but small radiation exposures—will require massive expenditures on a scale which has heretofore been restricted to certain aspects of the physical sciences.

3) If we are to increase our scientific efforts, universities as a whole must be strengthened. We favor unprogramed grants made on the basis of carefully devised plans, subject to review after a period of years, and available for the support of research and the training of graduate students in a designated area, rather than on a specific project. Research functions at such institutions cannot be separated from teaching functions.

4) It is essential to maintain and increase the diversity of sources of governmental and private support for basic research. Such diversity of sources provides a way to secure diversity of judgment and to maintain freedom.

5) We favor prompt and thorough consideration of the possibility of carrying out adjustments in the tax structure of the nation which would increase the amount, diversify the sources, and equalize the cost to contributors, both corporate and private, of the support of education and research. (*Note*: This recommendation was approved by a vote of approximately three to two. The proportion of negative votes was greater than that for any other recommendation. It was noted by the participants that a study of proposed tax changes was being conducted for the AAAS.)

6) Scientific development would be accelerated if a greater proportion of the total research and development funds were invested in basic research. In the anticipated period of rapid scientific advance, the demands of development make very clear the underlying need for increased emphasis on basic research in sciences and engineering.

7) In the appropriation of funds for the National Science Foundation, care should be exercised to ensure that the support of basic research is not subordinated to programs in support of education in the sciences.

Two points should be made: (i) The training of young research men is significantly advanced by their participation in research projects. Moreover, research grants increase the effectiveness of personnel needed not only for research, but also for teaching. (ii) A large expansion of the fellowship program imposes a financial burden on the universities. This needs to be compensated by grants to the universities covering the full cost, just as research grants should provide for full coverage of indirect costs.

8) The government has the responsibility for ensuring adequately broad support of research by stimulating other sources of support and supplementing them. We favor a decision at the highest levels of government which would establish a stable base in terms of which the core amount to be provided by the Federal Government may be predetermined, but may be subject to review and reappraisal at intervals. This is peculiarly needed in the support of research where effective use of funds requires assurance of continuity and stability.

9) In general, close and effective contact, both intellectual and geographic, should be maintained between research institutes and universities to assure maximum utilization of research facilities for the training of graduate students. But when there are obviously special needs of equipment and location, as in astronomy, research institutes separate from universities are justified.

10) The welfare of the sciences must not be secured at the expense of other segments of the university.

Report of Section II, Organization and Administration of Science in Government

Section II was assigned the very broad topic of "Organization and Administration of the Nation's Scientific Effort." This problem is so vast that the section felt that of necessity the topic had to be delimited in some way. Since planning on a national scale must be done mainly by the Federal Government, and since a large part of the financial support for research comes from Federal sources, the section addressed itself mainly to the problems of the Federal Government. Time did not permit consideration of the important roles of private agencies and of local and state governments.

When one speaks of broad-scale planning for the national organization for science, one must include not only a determination of the broad fields which should receive support but also the problem of proper utilization of the scientific manpower that will come in increasing numbers from the colleges and universities.

Recommendations. The actions taken by the group may be divided into the following headings:

A) A means of providing advice to the top-policy levels of government, as well as the planning for expenditure of large amounts of money and for the coordination of government research activities.

B) Contract and Civil Service laboratories.

C) Research laboratories and institutes.

D) The organization of research and development in the Department of Defense.

A) *Scientific Advice—Scientific Planning on the National Scale.* Science and technology have an impact on national policy both domestic and foreign. Science and technology are supported by the government both within government and outside of government. Furthermore, science and technology are utilized by government to perform its functions. Both functions require planning and coordination in the operational sense and in fact require planning on a national scale.

11) The group felt, in regard to the impact of science and technology on national policy, that this requires representation of science and technology at highest levels in government where such national policies are formulated. Such representation will also provide the necessary interpretation in the evolution of national policy for science and technology.

12) The present plan with Dr. J. R. Killian, Jr., as special assistant to the President does seem to furnish the necessary high-level representation, and we strongly endorse the continuation of such an arrangement.

13) The establishment of a department of science which would have jurisdiction over all scientific activities of the government is undesirable at this time because: (i) Many scientific activities of the government are integral parts of the missions of existing departments and should remain within those departments. (ii) To set up a department of science for basic research alone is undesirable since it would segregate exactly those parts of science least relevant to political issues and place them under the direction of a cabinet officer who is automatically and properly a political appointee.

14) We recognize and endorse the importance of the National Science Foundation in coordinating basic research among all agencies, both governmental and nongovernmental.

15) The role of the National Academy of Sciences–National Research Council as nongovernmental agencies through which advice to the government is rendered upon its request is strongly supported.

16) The group addressed itself only to the basic research aspects of science and technology. The various departments and agencies in government that support or perform research should continue to be free to engage in basic research as they recognize needs related to their operating responsibilities. As over-all funds for research increase, it will be necessary to do more planning and give closer scrutiny to national policy. By statute, the National Science Foundation has been given major responsibility for formulating national scientific policy. This function will become more important as the availability of funds increases. In addition to expanding the horizon of national planning, the NSF should encourage support for research in universities and research institutions. The procedures to be used in making funds available may require modification to give more flexibility to those performing the research. This can be accomplished by permitting the Foundation to use its judgment regarding allocation of appropriated funds, rather than by following the present procedure, in which the Bureau of the Budget and the Congress must give approval to specific items.

B) *Contract and Civil Service Laboratories.* The group discussed the general problem of research laboratories operated by contract, as for example under the Atomic Energy Commission, and those operated by the government under Civil Service. This dualism creates different salary scales and different modes of operation.

Both types of operation seem to have their proper place. Although some high-grade research laboratories are operated within the government framework, all suffer from the hampering influence of Civil Service personnel policies and regulations.

17) Basic research should be carried on in government laboratories, partly because basic research is often a necessary prerequisite to applied research and partly because some basic research will be necessary if personnel of high quality are to be secured and retained.

18) It is highly desirable to organize retirement plans, insurance benefits, etc., so that a given individual may transfer from university to government and vice versa in middle life without danger of losing such benefits. The same problem arises between universities and to some extent between both government and universities and industry.

C) *Research Laboratories and Institutes.* The group discussed at some length the need for new research laboratories and institutes. Separation of basic research from teaching is on the whole not advisable, although for specific problems it may from time to time be necessary to create new research institutes.

Agreement was reached on the following points:

19) An increase in the number of universities with strong research programs and training at the graduate level is highly desirable. In increasing the number, it is particularly important to widen the geographic distribution of such universities.

20) Increased staffs, with teaching loads so adjusted as to encourage research, are essential. Funds for capital expenditures for buildings and equipment must also be found.

21) Research centers should wherever possible be associated with the teaching function.

D) *Defense.* The group discussed at some length the problem of research in the Department of Defense. The problems which affect the type of research and the recruitment of personnel in defense establishments are numerous.

The group as a whole accepted the following points:

22) The structure of research and development in the Department of Defense should be subjected to continuous reexamination.

23) Able administration of research must be ensured, possibly by career officers who are not subject to frequent rotation but more probably by civilians who would be allowed to attain high administrative posts.

24) Decision between contract and civil-service operation was not made. Each probably will be necessary for certain specific problems, but government operation not by contract will be essential for many installations.

25) The following points should also be stressed: (i) Greater continuity of budgets is desirable. (ii) Greater responsibility for programing should be placed on operating agencies. (iii) Special agencies may be created for specific or crash programs.

Report of Section III, Communication among Scientists and Communication of Scientific Ideas

The problems of communication are considered under two headings: (i) communication among scientists and (ii) communication between scientists and the public.

The following recommendations are directed in some cases to scientists themselves, in other cases to the government, to fund-granting agencies, to the press, or to the general public.

The following propositions provide a basis for specific recommendations.

A) Communication among scientists and between scientists and the public is an essential part of research.

B) It is important that the findings and conclusions of the scientist be presented as effectively as possible to both groups.

C) Agencies supporting research have a responsibility to contribute to the cost of publication and to the cost of personal contact among scientists at local, national, and international levels. These two types of communication are important contributions to the development and use of new knowledge.

D) It is to the public interest that every effort be made to preserve and strengthen those freedoms which are universally recognized as essential to the pursuit of study, research, and communication.

Recommendations concerning Communication among Scientists. 26) It is recommended that scientists themselves improve the presentation of papers by use of clear, vigorous English with correct technical terms and nomenclature, and improve the quality of what is communicated by supporting critical and responsible editorial policies in scientific periodicals. To this end we urge more systematic attention to expository writing on the part of graduate students in science.

27) It is recommended that research-supporting agencies: (i) Provide financial support where it is needed to ensure that publication is not withheld because of lack of funds; (ii) Recognize that monographs, abstracts, indices, reviews, compendia, books, bibliographies, and proceedings of symposia are important means of communication and that scientists should be supported in their preparation. (iii) Encourage and support scientific meetings as an effective method for the exchange of information and the education of young scientists and the public, and small seminars (of sufficient duration for effective communication) as an essential method of communication among research scholars. (iv) Provide adequate support for research on new devices for recording, storing, and retrieving scientific information.

28) It is agreed that the emergence of Russian as an increasingly important language makes it essential to provide translating services and to encourage universities to offer instruction in this language.

Recommendations concerning Communication between Scientists and the Public. In the past, progress in scientific research has been paralleled by similar progress in communications between scientists and the public. This has been marked by a gratifying improvement in the relationships between many scientists and many science writers and a growing understanding by each of these groups of the problems and responsibilities faced by the other.

More significantly, this advance in communication has led to a growing appreciation and understanding of science by the public. In the past this has been desirable; today it is essential. Without public understanding of science in a democracy, neither democracy nor science can hope to survive.

Where do we stand now? The facts are more encouraging than many scientists realize. Recent data clearly indicate that news of science is already read widely by the public, that there is a firm demand by readers on all educational and economic levels for more science news, and that public understanding of the scientist and his work is becoming increasingly accurate and realistic.

These same data make it clear, however, that the problems of communication between scientists and the public have not been entirely solved. Further progress depends on increased participation of scientists in helping to clarify scientific achievements and their social consequences. This in turn requires the further understanding and acceptance by scientists of certain basic concepts of communication.

These are: (i) The work of the scientist is not truly completed until its significant results are communicated not merely to other scientists but to the public at large. (ii) In communication between scientists and the public, full use should be made of all media of public information. (iii) In developing communication between scientists and the public, the major role must be undertaken by science writers or other interpreters with professional training and standards. This does not absolve scientists of their responsibility to communicate directly with the public when they can do so. (iv) Scientists have not merely the right but the obligation to speak out against quacks, charlatans, and pseudo-scientists. (v) Except when necessary for national security, governmental censorship and restrictions on the dissemination of information in science are destructive, wasteful, and intolerable in a democratic society.

Acceptance of these principles logically suggests the following specific actions for their prompt implementation.

29) Since there is an increasing need for skilled science communication, scientists and their organizations should assume part of the responsibility for training science writers in both government and private research facilities and universities. Specifically, the American Association for the Advancement of Science and other representative scientific organizations should cooperate formally with the National Association of Science Writers and other agencies now conducting such training programs. In addition, enabling legislation is recommended so that funds may be provided by such appropriate agencies as the National Science Foundation and the National Institutes of Health to assist in these training programs.

30) Scientists and their organizations

should join actively in the efforts of the American Society of Newspaper Editors, the American Bar Association, and other agencies now concerned with reducing governmental secrecy and protecting the public's right to know.

31) In addition to utilizing standard mass media of communication, individual scientists and their organizations should make increasing and experimental use of other means of contact between scientist and the public—in adult education programs, local discussion groups, and science fairs. Specifically, for example, the AAAS and the international scientific unions are urged to cooperate in the sponsorship of such appropriate ventures as the forthcoming World's Fair of Science.

32) In order to facilitate wise public decisions, scientific organizations have the responsibility to present, where possible, evaluations of available facts on controversial public problems involving the social consequences of their fields of activity. Science does not speak with a single voice; in many cases there will be divergence of opinion among scientists themselves. Yet it is desirable to reduce, not increase, public confusion. One recently attempted solution is the appointment by scientific organizations of expert committees to clarify for the public the evidence and the possible interpretations of its meaning. Other solutions must be sought.

Report of Section IV, The Selection, Guidance, and Assistance of Students

The advance of education is dependent upon support for faculty and institutions as well as for students.

We recognize the need for increased support for students in all fields of educational endeavor. Therefore funds must be provided not only for the support of students in mathematics, the natural sciences, and technology but also for those in the humanities and the social sciences.

All citizens should have an opportunity to become familiar with the processes, procedures, and findings of scientific endeavor. This requires education of all students to the full potential of their talent and motivation both during school years and thereafter.

Recommendations. 33) The Federal Government should not assume the entire burden of the expanding education program. It is essential that states and local communities and other agencies recognize their responsibilities in promoting and improving the entire educational effort.

34) Support and encouragement for high quality education in the sciences is needed at all levels of education.

35) Programs of counseling, guidance, identification, and motivation of talented students should be developed through the cooperative efforts of institutions of higher learning and elementary and secondary schools.

36) There is a serious shortage of counselors. We recommend that both "short term" and "regular" institutes for counselors and teachers be supported by grants from the Federal Government.

37) Testing for identification of abilities and for guidance should begin in the elementary school and should be a diversified and continuing process. Responsibility for testing rests with states and localities, but Federal support should be available, where necessary, to get such testing started.

If there are Federal scholarships, selection of recipients should be made at the state level, using tests as one factor.

38) At best a federal undergraduate scholarship program for high school seniors is only one facet of the necessary support of education. It carries within itself the danger of concealing other essential steps.

39) Scholarships and fellowships, the cost of which is defrayed from Federal funds, should be awarded solely on the basis of merit. In a federal scholarship program there should be no restriction upon choice of specialty by the student.

40) Fellowship programs in science should recognize the importance of complementary fellowships in the humanities and in the social sciences.

41) Fellowship and grant programs should be made realistic in terms of support to the fellows, their families, and the institutions they attend.

42) A satisfactory fellowship program depends upon the quality of teaching and on the institutional resources. This quality varies greatly in different institutions. Therefore, cooperation among educational institutions should be encouraged to develop their different strengths.

43) Students' interest and competence can be enhanced by a variety of means in addition to scholarships. For example: (i) Summer institutes in science, mathematics, social sciences, and the humanities for superior high school students should be organized and operated by colleges and universities. Desirable summer institutes for high school students can be provided through demonstration classes such as are now supported by the NSF at some institutes for teachers. Selection for a summer institute is one means of rewarding intellectual achievement and of motivating students toward scholarly activities. (ii) Schools and colleges should emphasize programs which permit gifted students to learn more and to benefit by each other's intelligence and by superior teaching. Offering college level work for superior high school students is one means to these ends. (iii) In addition to training the critical faculties of students, more emphasis should be laid on the development of the creative and imaginative capacities.

Report of Section V, Improvement of Teaching and Education

We believe that the primary goal of education should be the intellectual development of the individual. With its accelerating importance in our society, science has become an increasingly important part of general knowledge. We believe that scientific education is best fostered as a part of a general emphasis on intellectual activity and that the pressing need is for increased support of the social sciences and humanities as well as the natural sciences.

Curriculum. 44) *Science Teaching.* The teaching of science should give due emphasis to the nature of science itself. It should not be simply a collection of facts. It should show the way in which scientific conclusions are drawn by rational processes from observations and should emphasize the tentativeness of these conclusions. It should keep alive that curiosity and enthusiasm for learning which are so necessary for all intellectual pursuits.

45) *Research in Education.* We recommend the support of research designed to improve the methods of attaining the educational goals set forth in the two preceding paragraphs.

46) *College Entrance Requirements.* We believe that education in science, mathematics, and other subjects could be improved by generally raising university and college entrance requirements. This should be done in consultation with secondary schools so that the requirements can be based on mutual understanding.

47) *Special Schools.* We oppose the creation of a special "West Point of Science" or any federal educational institution devoted solely to science training.

48) *Students of Exceptional Ability.* We urge that efforts be made to recognize at an early age students with high intellectual competence and that opportunities be made available for them to receive education commensurate with their abilities.

49) *Languages.* In view of the crucial role that languages play in scientific communication, because of the great increase in international travel and communication and because of the ease with which languages are learned by the young, we urge that foreign-language instruction be made available to students in grade schools and be strengthened in high schools and colleges.

Teaching. 50) *Salaries and Recognition.* The urgent need to develop fully the intellectual resources of our nation requires a prompt and thorough recognition of the basic importance of education in our society. Our schools and colleges will be able to contribute fully to the solution of the problems that now confront us only if the improvement of the teaching profession is accorded a high priority among our major concerns. We must compensate teachers at levels which reflect the degree to which the destiny of the nation depends on teaching of the highest quality. Only through such a realistic approach can we hope to solve the quantitative and qualitative shortages which now seriously limit what schools and colleges are able to accomplish.

Preparation and Certification of Teachers in Elementary and Secondary Schools. 51) We recommend that the minimum requirements for academic subject courses for the certification of science teachers be raised to such a level that the teacher has a reasonable mastery of his subject.

52) We recommend the continuance and expansion of teacher training programs, such as those sponsored by the National Science Foundation. We urge state and local groups, both public and private, to lend their support, financial and otherwise, to programs that increase the subject-matter knowledge of people now teaching science.

53) We recommend that credit toward professional advancement be given to postgraduate work in academic subjects related to the teaching field even when these do not carry graduate credit or count toward a graduate degree.

54) We recommend that universities and colleges develop master's degree programs in sciences which are specifically designed to meet the needs of teachers.

55) We believe that in many cases it is possible to reduce the number of hours in professional education courses required for certification or graduation, and that the corresponding increase in opportunity for other courses would improve teaching effectiveness.

56) We recommend that certification requirements in the several states be revised to make it possible for a college or university to prepare teachers for any state, and to facilitate the movement of teachers from state to state.

57) We recommend that scientists and scientific organizations take the initiative in cooperating with various state and local groups concerned with primary, secondary, and college teaching.

58) *Merit Increases.* We believe that in principle merit salary increases are desirable. A carefully administered system of salary increases based in part on merit is one means of increasing the attractiveness of teaching careers for students of superior competence.

59) *Use of College and University Students in Teaching.* We believe that a potential reservoir of teaching talent lies in college and university students. We recommend that ways be found for using such students of special ability in various ways, such as in summer institutes for gifted secondary school students.

60) *Science Supervisors.* We recommend that in each state there be one or more scientifically qualified science consultants or supervisors in departments of public education or universities to have such functions as (i) representing science and scientists in the formation of educational policy; (ii) serving as a liaison between scientists and teachers; and (iii) collecting and distributing to teachers information helpful in science instruction.

Priorities. 61) It is the sense of this group that federal and other funds for improvement of science education be assigned priorities as follows: (i) improvement of education and encouragement of teachers by better salaries and opportunities for further learning; (ii) new construction, facilities, and equipment; (iii) scholarships.

General Conclusions

Under the auspices of the American Association for the Advancement of Science, a representative group of over 100 American scientists and public leaders met in Washington on 15–17 March 1958 to consider current and pressing problems of the support of science and the improvement of education. These problems in large measure have resulted, directly or indirectly, from the rapid expansion of scientific knowledge and its technological application. This Parliament of Science reached a number of conclusions which are set forth above. Underlying the specific conclusions are a much smaller number of general principles upon which the participants agreed.

1) Scientific endeavor is one phase of human intellectual effort; the degree to which it flourishes depends largely upon the extent to which intellectual effort generally is supported and encouraged.

2) Optimal progress in science requires increased support for basic research.

3) As funds for the support of science increase, it becomes increasingly necessary to formulate appropriate plans and procedures for the administration and correlation of the total scientific effort and to give closer scrutiny to national scientific policy.

4) In order that science may progress most effectively, and in order that science may be wisely used for the improvement of human welfare, scientists must have the maximum possible freedom to communicate with each other, both in person and by publication, and to communicate with the public.

5) Scientists are dedicated to the finding of new knowledge. As citizens, they have the responsibility to concern themselves with the social consequences of their scientific findings and to inform the public of the consequences they foresee.

6) The primary goal of education is the intellectual development of the individual. The primary need of education is to employ quality and to raise standards—of teachers, of curricula, and of what is expected of students.

7) In the assignment of funds to the improvement of education, first priority should go to improvements in curricula, teaching, and the status and salaries of teachers.

The Parliament of Science sponsored by the American Association for the Advancement of Science illustrates a way whereby scientists may appropriately consider the social consequences of their findings. Future conferences of a similar sort could further explore problems of science and public policy.

Mammalian Viruses and Rickettsiae

Their purification and recovery by cellulose anion exchange columns has significant implications.

Bill H. Hoyer, Ellis T. Bolton, Richard A. Ormsbee, George LeBouvier, Daniel B. Ritter, Carl L. Larson

Peterson and Sober (*1*) and Sober *et al.* (*2*) described the preparation of the cellulose ion exchangers, DEAE-SF and ECTEOLA-SF, and their use in column chromatography of proteins. The observations of Commoner *et al.* (*3*) on the chromatography with ECTEOLA-SF of natural tobacco mosaic virus and reconstituted virus nucleoprotein, as well as those of Taussig and Creaser (*4*) and Creaser and Taussig (*5*) on chromatography and purification of T1, T2r, and T2r+ bacteriophages with this cellulose ion exchanger, suggested its use in chromatography of animal viruses. This article reports the results of exploratory chromatographic studies on the purification of several representative animal viruses and rickettsiae. It demonstrates that the chromatographic procedure provides high yields of purified infectious agents and discusses some of the implications of the findings for further fundamental and applied research.

Methods

ECTEOLA-SF and DEAE-SF cellulose anion exchangers were used for column chromatography and purification of poliomyelitis (Mahoney, type 1, Lansing, type 2, and Saukett, type 3), ECHO (type 13), and Coxsackie (type A9) viruses from ultracentrifuged concentrates of tissue-culture fluids from infected monkey kidney or Detroit-98 (D-98) cells (*6*). The behavior of concentrates of Q fever and of epidemic typhus fever rickettsiae from chick-embryo yolk sacs and of Colorado tick fever virus in homogenates of brains from infected suckling mice was also examined.

Preparations of ECHO, Coxsackie, and polio, types 1 and 3, were made from infected monkey kidney cell monolayers in MS solution (*7*) containing 5 percent calf serum. Polio, type 2, was prepared from D-98 cell monolayers in Eagle's HeLa cell medium (*8*) with 5 percent horse serum added. Virus concentrates were prepared from tissue-culture fluids clarified by centrifugation at 3500 *g* for 30 to 60 minutes, followed by centrifugation at 100,000 *g* for 1 to 2 hours. The sediments were suspended in 0.01 or 0.02*M* phosphate buffer, *p*H 7.1, then recentrifuged at 100,000 *g* for 1 to 2 hours, and finally resuspended in phosphate buffer. Partially purified concentrates of epidemic typhus and Q fever rickettsiae were made from infected chick-embryo yolk sacs by a modification of Bovarnick and Snyder's method (*9*). The preparations of Colorado tick fever virus were homogenates of 20 percent (wt./vol.) suspensions, in 0.02*M* phosphate buffer, of brains from infected, moribund, suckling mice.

Several virus preparations were made from appropriately infected tissue cultures grown in the presence of phosphorus-32 in order to label the virus particles with a radioactive tracer. In such cases, MK or D-98 cells were overlaid with Eagle's medium modified to contain 0.001*M* citrate buffer instead of phosphate buffer. To this medium was added 2.5 μg of KH_2PO_4 per milliliter, 0.01 to 0.07 mc/ml of carrier-free P^{32} as orthophosphate, and dialyzed calf or horse serum (2 or 5 percent).

Columns of cellulose ion exchangers 1 cm in diameter and 7 to 13 cm in length were employed. Such columns contained 1.3 to 2.4 g of ECTEOLA-SF (0.2 milliequivalent/g) or 0.7 to 1.4 g of DEAE-SF (1.0 milliequivalent/g). Preparations of viruses and rickettsiae were loaded onto the columns in 1- to 5-ml quantities and eluted with successive 1-ml quantities of phosphate buffer, or phosphate buffer containing increasing concentrations of NaCl; volumes of 10 to 20 ml of each eluent were used. The usual elution schedule was as follows: 0.01*M* phosphate buffer, 0.02*M* phosphate buffer, 0.1*M* NaCl in 0.02*M* phosphate buffer, 0.25*M* NaCl in 0.02*M* phosphate buffer, and 0.5*M* NaCl in 0.02*M* phosphate buffer. Columns were operated under air pressure of about 6 lb/in.^{2} with flow rates of approximately 0.5 ml per minute.

Titrations of eluates were made with tenfold serial dilutions placed in tubes containing monkey kidney tissue cultures, and the endpoints, in terms of tissue-culture doses (TCD_{50}), were calculated by the method of Reed and Muench (*10*). Colorado tick fever virus was similarly diluted, although it was necessarily titrated in suckling mice. The radioactivity of dried samples in planchets was assayed with a mica, end-window Geiger-Mueller tube (1.8 mg/cm^2) and a decimal scaler.

Rickettsiae

Figure 1 strikingly illustrates that adsorption from 0.02*M* phosphate onto ECTEOLA-SF and elution with 0.1*M* NaCl in 0.02*M* phosphate buffer and 0.2*M* sucrose removed nearly all contaminating material from partially purified suspensions of Q fever rickettsiae. Preparations suspended in 0.02*M* phosphate buffer containing 0.1*M* NaCl and 0.2*M* sucrose were air-dried on Formvar membranes, fixed with osmic acid vapor, washed with distilled water, and shadowed with a platinum-palladium alloy. Yolk-sac material, still present despite differential centrifugation and celite treatment (Fig. 1, top), was removed by one passage through an ECTEOLA-SF column (Fig. 1, middle and bottom). Similar results were obtained with epidemic typhus rickettsiae.

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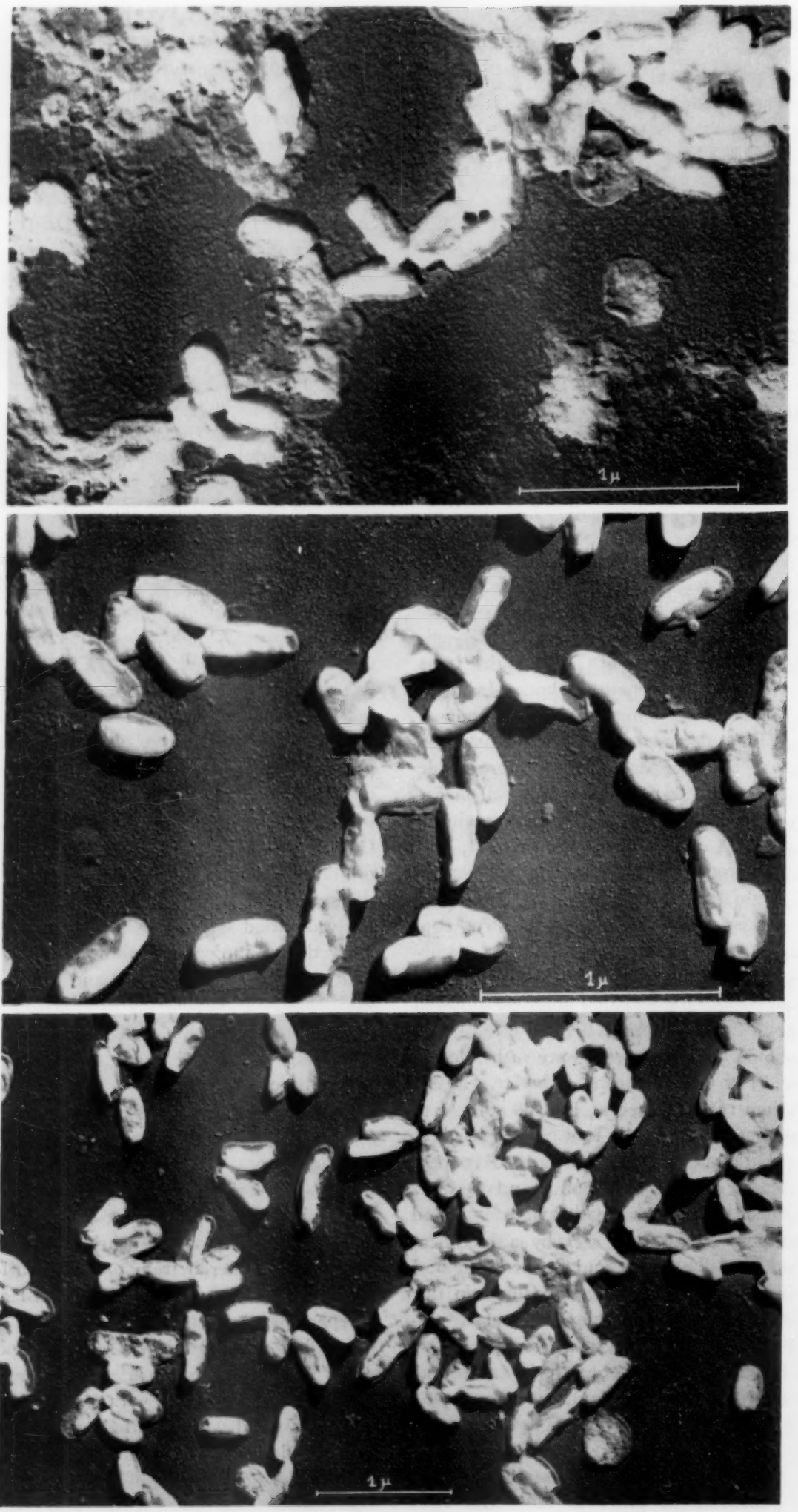

Fig. 1. Electron micrographs of Q fever rickettsiae. (Top) "Purified" (*9*) rickettsiae. (Middle) Rickettsiae from the same preparation after adsorption onto an ECTEOLA-SF column and elution by 0.1*M* NaCl at comparable magnification. (Bottom) Typical low-magnification field of a purified preparation. Rickettsiae were prepared for observation and electron micrographs were made by Edgar Ribi and William R. Brown of the Rocky Mountain Laboratory.

Viruses

Table 1 summarizes the chromatographic behavior of the viruses studied. The viruses, as determined by titration, emerged from the columns in well-defined regions of the eluate and invariably in excellent yield.

ECHO. Preparations of ECHO-13 virus, concentrated from tissue-culture fluids from monkey kidney cells infected in the presence of P^{32}, were adsorbed onto ECTEOLA-SF and eluted. Eluates containing viable virus were pooled, concentrated by centrifugation, and readsorbed onto an ECTEOLA-SF column from 0.01*M* phosphate buffer at *p*H 7.1. The virus could again be eluted with 0.1*M* NaCl (Fig. 2). Results which relate the amount of virus recovered and the radioactivity eluted are illustrated in Fig. 2. This figure shows that 88 percent of the virus recovered was in 1 ml of eluate. This fraction contained most of the radioactivity (0.3 count/min per 2000 tissue-culture doses). ECHO-13 could also be eluted from DEAE-SF by 0.1*M* NaCl, as determined by titration, although the elution diagram showed appreciable tailing.

Coxsackie. Coxsackie A9 virus, from a P^{32}-labeled tissue-culture fluid concentrate, suspended in 0.02*M* phosphate buffer, readily passed through an ECTEOLA-SF column, and 98 percent of the added virus appeared in the first few milliliters of effluent (Fig. 3). This effluent contained only 5 percent of the radioactivity initially present in the preparation.

Poliovirus. Polio, type 2, derived from infected, P^{32}-labeled D-98 cells and suspended in 0.02*M* phosphate buffer was passed through an ECTEOLA-SF column. Titratable virus and radioactivity showed definite correspondence (Fig. 4) although less than 4 percent of the radioactivity added to the column appeared in effluents containing 99 percent of the detectable virus. Most of the titratable virus appeared before the fifth milliliter of 0.02*M* phosphate buffer had passed through the column (Fig. 4*A*). The elution of this virus from DEAE-SF was similar to that from ECTEOLA-SF, but less sharp. Effluents which contained virus were pooled and reexamined chromatographically as follows: Without further treatment, one portion was again chromatographed. The elution pattern was identical with that of the virus-containing portions of the original tissue-culture fluid concentrate (Fig. 4*B*).

About 0.4 counts/min per 2000 tissue-culture-doses were found in the 1-ml fraction which contained most of the detectable virus. Another portion was dialyzed, first against running tap water and then against 0.02*M* phosphate buffer. Eighty-five percent of the radioactivity was retained within the dialysis bag despite prolonged and repeated dialysis. In addition, 78 percent of the radioactivity of another aliquot was found in the sediment after centrifugation at 80,000 *g* for 100 minutes. The elution diagram of a portion of this non-dialyzable material was identical with that of polio 2 virus derived from the crude concentrate or from column eluates. These findings demonstrated that the chromatographic behavior of the virus remained constant during these treatments.

Ultraviolet absorption spectra of polio 2 preparations (10^{10} TCD_{50}/ml) purified by passage through an ECTEOLA-SF column possessed a characteristic nucleoprotein absorption peak at 260 mμ which was not apparent in the spectrum of the input material (Fig. 5).

Poliovirus, type 1, concentrated by centrifugation, washed, and resuspended in 0.01*M* phosphate buffer, *p*H 7.1, was added to an ECTEOLA-SF column. The major portion was recovered in the first eleven milliliters of 0.01*M* phosphate buffer eluent. Type 3 poliovirus in tissue-culture fluid, diluted 1:10 with 0.02*M* phosphate buffer, *p*H 7.1, and added to an ECTEOLA-SF column, was recovered in the first five milliliters of the initial eluent, 0.02*M* phosphate buffer. These findings do not necessarily imply different elution characteristics for these polioviruses, since the initial conditions were not comparable.

Colorado tick fever. Five milliliters of Colorado tick fever virus, in the form of 20 percent mouse-brain homogenate, were adsorbed onto a 10-cm ECTEOLA-SF column. Elution results are given in Table 2. Most of the titratable virus (67 percent) was eluted by 0.50*M* NaCl in phosphate buffer, whereas only 13 percent of the total protein added to the column was recovered in this fraction. Thus, partial virus purification was achieved, even from very crude starting material, and virus recovery was satisfactory.

In the experiments described, material loaded onto the columns (except for the Colorado tick fever suspension described above) generally contained from 0.2 to 1.0 mg of protein [0.7 to 3.5 absorbance units determined by the procedure of Lowry *et al.* (*11*); protein values are expressed in terms of a standard solution of crystallized bovine albumin, Armour and Co., Chicago, Ill.]. Eluates with the major portion of titratable virus usually contained less than 20 μg of protein per milliliter. When these eluates were again adsorbed and eluted, protein was generally not detectable (less than 1 μg) in the virus-containing fractions, although most of the virus was recovered.

Discussion

The foregoing data indicate that rickettsiae and some mammalian viruses can be adsorbed onto and selectively eluted from ECTEOLA-SF and DEAE-SF columns. The conditions under which this can be accomplished also permit the recovery of essentially all the virus added to the columns and allow the removal of much extraneous substance.

Coxsackie A9, and poliovirus, types 1, 2, and 3, did not appear to be ad-

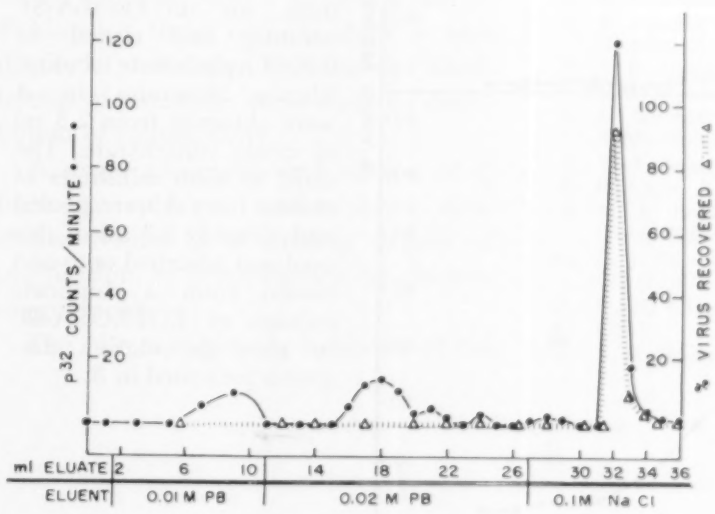

Fig. 2. Relationship between virus recovery and radioactivity (P^{32}) from a preparation of ECHO-13 virus grown on P^{32}-labeled monkey kidney cells, adsorbed onto an ECTEOLA-SF column, and eluted by 0.1*M* NaCl.

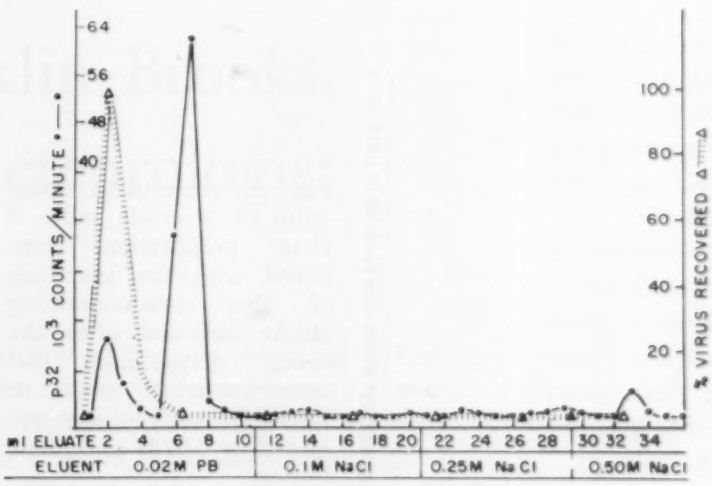

Fig. 3. Relationship between virus recovery and radioactivity (P^{32}) from a preparation of Coxsackie A9 virus grown on P^{32}-labeled monkey kidney cells, adsorbed onto an ECTEOLA-SF column, and eluted by 0.02*M* phosphate buffer.

Table 1. Summary of elution characteristics of viruses and their recovery from ECTEOLA-SF and DEAE-SF columns.

Agent	Source	Eluent*	Titers of virus†	
			Total added	Eluate
Polio 2	Tissue-culture fluid	0.02*M* phosphate buffer	9.0	8.8
Polio 2	Tissue-culture fluid	0.02*M* phosphate buffer*	8.6	8.6
Colorado tick fever	Mouse brain	0.5*M* NaCl	8.9	8.8
ECHO-13	Tissue-culture fluid	0.1*M* NaCl	5.3	5.4
ECHO-13	Tissue-culture fluid	0.1*M* NaCl*	6.8	6.8
Coxsackie A9	Tissue-culture fluid	0.02*M* phosphate buffer	9.6	9.3
Polio 1	Tissue-culture fluid	0.01*M* phosphate buffer	7.8	8.0
Polio 3	Tissue-culture fluid	0.02*M* phosphate buffer	7.5	7.5

* Virus first appeared in large quantity when columns were eluted with phosphate buffer or PB + NaCl in the concentration noted. Those eluents marked by asterisks indicate that results were obtained with DEAE-SF; all others were obtained with ECTEOLA-SF.

† Virus titrations are expressed as $\log_{10}$ of the TCD_{50} or LD_{50}. The titer in the column "Eluate" refers only to the virus released by the eluent noted in column 3.

sorbed under the conditions employed, since they appeared in the very early fractions of the initial eluents. In spite of this behavior, a considerable degree of purification can be achieved. For example, most of the contaminating, phosphorus-containing material can be adsorbed by the ion exchanger and can be separated from the infectious particles. Furthermore, most of the extraneous protein can be adsorbed by the ion exchanger and also separated from the virus. The close correspondence between virus activity and P^{32} distribution also indicates that marked virus purification was accomplished with ECHO-13 and polio 2 viruses. These data indicate the practicality of simply and effectively labeling and purifying useful quantities of infectious mammalian viruses. Such viruses may well provide a much-needed material for studying virus-host relationships and the antigenic properties of animal viruses.

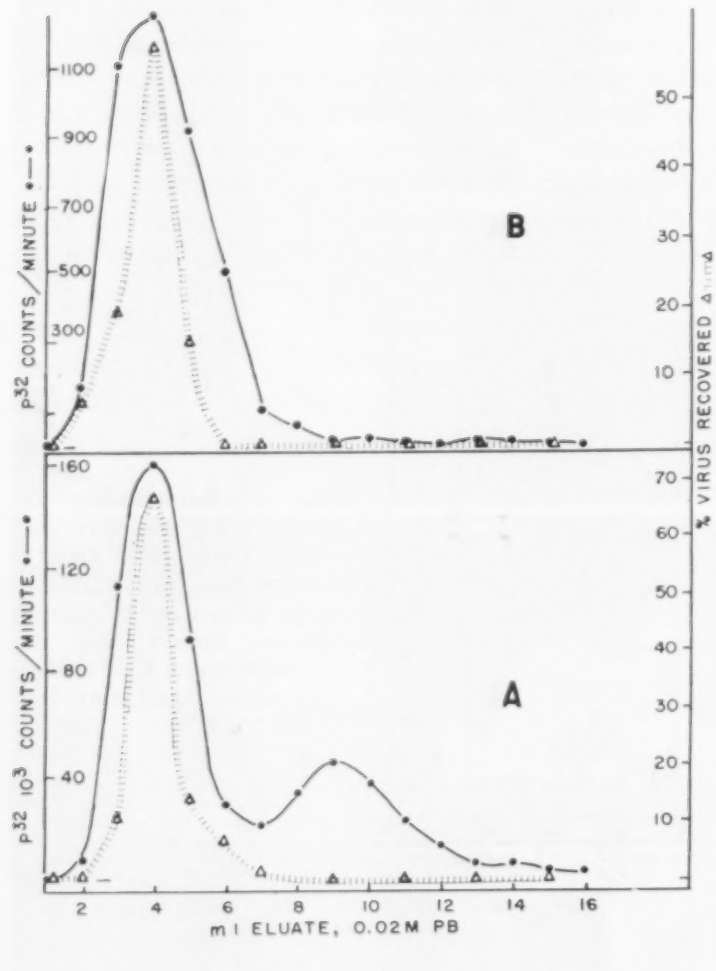

Fig. 4. Relationship between virus recovery and radioactivity (P^{32}) from a preparation of polio 2 virus grown on P^{32}-labeled Detroit-98 cells, adsorbed onto an ECTEOLA-SF column, and eluted by 0.02*M* phosphate buffer. Elution diagrams in *A* were obtained from 2.3 ml of crude concentrate. The third to sixth milliliters of eluates from *A* were pooled and diluted; 2.3 ml of this pool was adsorbed onto and eluted from a duplicate column of ECTEOLA-SF to give the elution diagrams presented in *B*.

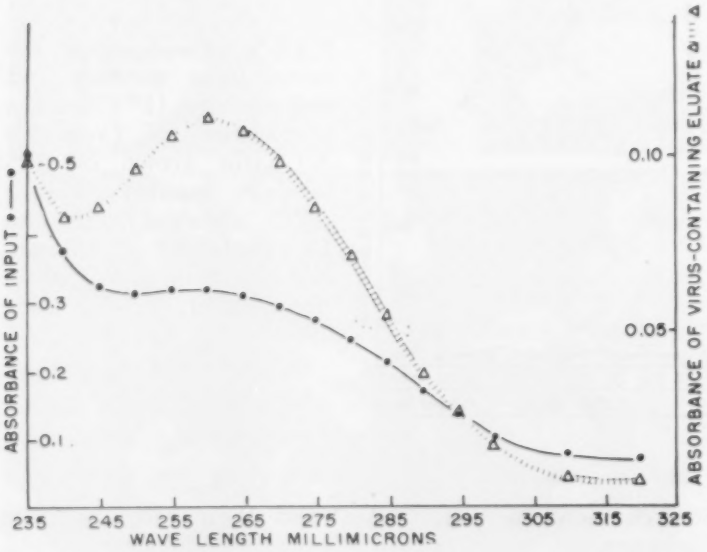

Fig. 5. Absorption spectrum of a crude polio 2 virus preparation compared with the spectrum of the virus-containing eluate obtained after the crude preparation had been adsorbed onto an ECTEOLA-SF column and eluted by 0.02*M* phosphate buffer.

Table 2. Behavior on an ECTEOLA-SF column of Colorado tick fever virus from a mouse-brain homogenate.

Preparation	Number of LD_{50}	Percentage of recovered virus	Protein content of eluates
Original	8×10^8		86 units*
0.02*M* eluate	0	0	8.8 units (10)†
0.10*M* eluate	1×10^8	11	9.2 units (11)
0.25*M* eluate	2×10^8	22	13.1 units (15)
0.50*M* eluate	6×10^8	67	11.1 unit (13)
Total recovered	9×10^8		

* A unit is equivalent to 270 μg of standard crystallized bovine albumin (Armour and Co., Chicago, Ill.) as determined by the procedure of Lowry *et al.* (*11*).
† The figures in parentheses indicate the percentage of original protein recovered in the eluate.

It is of particular interest that differences in chromatographic behavior, irrespective of particle size, have been demonstrated. Such different behavior must be presumed to be due to intrinsic differences in the surfaces of these agents. This is strongly suggested by the work of Taussig and Creaser on the coliphages (*4, 5*) in which the virus behavior in a column was shown to be determined by the character of the protein moiety. Among the viruses examined in the present investigation, ECHO-13 and Colorado tick fever are definitely different from each other as well as from the group comprising poliovirus, types 1, 2, and 3, and Coxsackie A9. ECHO-13 was eluted by 0.1*M* NaCl, whereas Colorado tick fever was eluted principally by 0.5*M* NaCl; in contrast, the other species studied passed through the column at very low salt concentrations. The character of the brain suspension may have modified the behavior of the Colorado tick fever virus on the column, but subsequent experiments with preparations containing very small amounts of brain material indicated similar elution behavior.

Rickettsiae, as exemplified by the organisms of Q fever and epidemic typhus, can be adsorbed and purified on cellulose exchangers. Rickettsial preparations of the purity indicated by the electron micrographs (see Fig. 1) are of obvious significance for studying rickettsial chemistry, metabolism, and immunology.

The experiments reported above are essentially exploratory. Nevertheless, the simplicity of this type of purification and examination of animal viruses encourages the hope that studies of these viruses will be concerned as much with the virus itself as with contaminating

host material. Elimination of contaminating host material from virus vaccines may be very important in reducing "side effects," such as allergic encephalitis, from vaccines which can be obtained only from tissues of whole animals. Chemical inactivations of viruses may also be carried out in systems relatively free of contaminants which would normally react with the inactivating agents and, thus, alter their effects on the viruses themselves. Differences in elution characteristics of the viruses presently investigated strongly suggest that surface properties of animal viruses can be investigated by means of chromatographic methods. In this connection, preliminary experiments (*12*) have shown that formaldehyde-treated polio 2 can be separated from untreated virus.

In general, we feel that procedures such as those described offer the definite hope that studies of animal viruses will no longer be hampered by the past difficulties involved in preparation of purified agents.

Summary

Techniques of column chromatography with cellulose ion exchangers have been successfully applied to mammalian viruses and rickettsiae. Recovery of virus is excellent, and appreciable purification in terms of phosphorus and protein removal has been demonstrated.

Elution characteristics of poliovirus (types 1, 2, and 3), and Coxsackie A9 virus are similar, whereas those of ECHO-13 and Colorado tick fever differ from them as well as from each other.

Elution diagrams of preparations of ECHO-13 and polio 2 viruses grown on P^{32}-labeled tissue cultures show a high degree of correlation between the distribution of titratable virus and the distribution of radioactivity.

A single adsorption and elution of Q fever or epidemic typhus fever rickettsiae results in a striking degree of purification, as demonstrated by electron micrographs.

The chromatographic behavior of the animal viruses and rickettsiae appears to depend more upon the chemical nature of the surfaces of these infectious agents than upon their size.

The chromatographic procedure described may prove useful in the preparation of purified, P^{32}-labeled, fully infectious animal viruses for further fundamental research. It may also prove useful for the removal of unwanted host materials in the preparation of vaccines.

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Charles Franklin Brooks, Meteorologist

Charles Franklin Brooks, professor of meteorology, emeritus, at Harvard University, died suddenly at his home on 8 January 1958, in his 67th year. Although he had retired last year from the directorship of Harvard's Blue Hill Meteorological Observatory, he had remained active in meteorological affairs; on the morning of his death he had made numerous samplings and measurements of the fresh snowfall.

Dr. Brooks's career spanned all the tremendous development in meteorology which has been concentrated in the present century. He was born in St. Paul, Minnesota. The severe summer thunderstorms which occur in that part of the country impressed him during his youth and served to spark his interest in the weather. He applied climatology early in life when he computed his rates for a contract in snow shoveling by the season versus rates per storm.

His university education was pursued at Harvard, where he received the A.B. in 1911, the A.M. in 1912, and the Ph.D. in 1914. His Ph.D. in meteorology was the second to be awarded in this country.

He went to Washington, D.C., to work on the *Atlas of American Agriculture*. Then he became instructor in geography at Yale University (1915–18). Later he served as instructor in meteorology for the U.S. Army Signal Service at College Station, Texas. Following this work he returned to Washington to edit the Weather Bureau's *Monthly Weather Review* (1918–21). For the next decade he taught meteorology and climatology in the Graduate School of Geography at Clark University.

The American Meteorological Society was founded in 1919 largely through the personal energy and enthusiasm of Dr. Brooks. He was elected secretary at the first meeting and served in that office until 1954. He was editor of the society's *Bulletin* during the first 19 years, and more recently he became known as "Mr. American Meteorological Society."

In 1931 he took the post of professor of meteorology at Harvard and director of the Blue Hill Meteorological Observatory. Under his directorship the observatory once more gained international recognition, as the staff and number of projects increased.

In 1940 the Weather Bureau Solar Radiation Field Testing Unit was moved from Washington, D.C., to Blue Hill at Dr. Brooks's suggestion, because the new location provided better exposure and proximity to other laboratories experimenting with the uses of solar energy. The Weather Bureau still maintains a solar observing unit at the Blue Hill Observatory.

In 1932 Dr. Brooks was instrumental in reestablishing a weather observatory at the top of Mount Washington. He became its president and engaged actively in this work until his death. Without his efforts, the Mount Washington Observatory almost certainly would have failed during times of crisis.

From the first few years of the Mount Washington observations he was able to illustrate their value to the Weather Bureau as aids in forecasting storms and cold waves. This, subsequently, led to the Bureau's support of the observational program. Liquid water content and icing rate of clouds were first routinely observed on the mountain. This work, always heartily endorsed by Dr. Brooks, led to many experiments in cloud physics and to the collecting of valuable data for the aircraft and tower industry, the latter having developed with the need for tall television and microwave towers.

Dr. Brooks's chief scientific studies have been on weather and climate. In his studies of the relations between ocean weather and synoptic meteorology, the difficulties and inaccuracies of meteorological measurements at sea became apparent. Studies of instrumentation and recommendations concerning the methods of observation followed.

At Blue Hill he prepared, jointly with A. J. Connor, basic climatic maps of North America which are still considered the best available for the area.

In the 1930's he set up a network of special weather stations over New England for the study of eclipse meteorology. His findings show the detailed changes in the weather which occur during an eclipse.

Under his direction the American chronometric radiosonde was developed at Blue Hill and, for a time, used routinely by the U.S. Weather Bureau and other countries. He studied the deficiencies of precipitation gages, designed and put into use new windshields which provide better "catch" during windy storms of rain or snow. His interpretation of clouds in terms of stability and general pattern of the atmosphere is well known among meteorologists. During World War II he taught new Weather Bureau and Civil Aeronautics Authority observers methods of cloud observation.

His knowledge of clouds, instruments, and methods of observation led the International Meteorological Organization, which later became the World Meteorological Organization, to utilize his experience in these matters in the late 1940's and early 1950's. He served this organization as a member of the committee which prepared the *International Cloud Atlas*. In 1953 he participated in the meetings of the Commission on Instruments and Methods of Observation of the World Meteorological Organization.

Although he was above all an observer, he heartily endorsed theoretical work in cloud physics and weather radar at Blue Hill.

In New England, Dr. Brooks has probably done more for the U.S. Weather Bureau than any other single person. He helped obtain a district forecast office in Boston, when previously the forecasts emanated from Washington. He was a strong advocate of hurricane research which could be applied to New England as well as to other areas, and he was constantly in touch with his senators and congressmen, emphasizing the needs of the Bureau. For nine years he and other staff members of the observatory studied snowstorms affecting the Boston area. This work helped to improve the forecasting of snowstorms for this area.

He was a fellow of the Royal Meteorological Society of Great Britain, a member of many scientific organizations in the United States, and, at one time, president of the Association of American Geographers. He served with the U.S. Quartermaster Corps, the Office of Scientific Research and Development, and the National Research Council.

His book, *Why the Weather*, published in 1921 and revised and enlarged in 1935, has served to inspire many to become meteorologists.

After the founding of the Lowell Broadcasting Council and of its radio station, WGBH–FM, whose transmitter is located on Blue Hill, he gave weekly talks on current events, both local and international, in the ever-expanding field of meteorology.

The most important phase of his career revolved around his unique personality. He worked and played at meteorology almost continuously, yet during all of this activity, Dr. Brooks showed a warm sympathy for all men, and he gave his time and energy unstintingly, day or night, to all who sought his advice—regardless of their academic degrees or lack of them.

JOHN H. CONOVER
Blue Hill Meteorological Observatory, Harvard University

News of Science

President's Message on Space Agency

President Eisenhower has proposed the creation of a National Aeronautics and Space Agency. He described the new agency on 3 April in a special message to Congress.

". . . An imaginative and well-conceived space program must be given high priority and a sound organization provided to carry it out. Such a program and the organization which I recommend should contribute to (1) the expansion of human knowledge of outer space and the use of space technology for scientific inquiry; (2) the improvement of the usefulness and efficiency of aircraft; (3) the development of vehicles capable of carrying instruments, equipment, and living organisms into space; (4) the preservation of the role of the United States as a leader in aeronautical and space science and technology; (5) the making available of discoveries of military value to agencies directly concerned with national security; (6) the promotion of cooperation with other nations in space science and technology, and (7) assuring the most effective utilization of the scientific and engineering resources of the United States and the avoidance of duplication of facilities and equipment."

Civilian control. "I recommend that aeronautical and space science activities sponsored by the United States be conducted under the direction of a civilian agency, except for those projects primarily associated with military requirements. I have reached this conclusion because space exploration holds promise of

adding importantly to our knowledge of the earth, the solar system and the universe, and because it is of great importance to have the fullest cooperation of the scientific community at home and abroad in moving forward in the fields of space science and technology. Moreover, a civilian setting for the administration of space function will emphasize the concern of our nation that outer space be devoted to peaceful and scientific purposes."

NACA to be absorbed. "I am, therefore, recommending that the responsibility for administering the civilian space science and exploration program be lodged in a new National Aeronautics and Space Agency, into which the National Advisory Committee for Aeronautics would be absorbed. Hence, in addition to directing the nation's civilian space program, the new agency would continue to perform the important aeronautical research functions presently carried on by the National Advisory Committee for Aeronautics. The new agency would be headed by a director appointed by the President and with the advice and consent of the Senate."

Space board proposed. "In order to assist the President and the director of the National Aeronautics and Space Agency, I recommend that a National Aeronautics and Space Board, appointed by the President, be created. Several of the members of the board should be from the Government agencies with the most direct interest in aeronautics, space, science, and space technology. To assure that military factors are considered by the board, at least one member should be appointed from the Department of Defense. Members appointed from outside the Government should be eminent in science, engineering, technology, education or public affairs and be selected solely because they have established records of distinguished achievements."

Agency's authority; salaries. "The National Aeronautics and Space Agency should be given that authority which it will need to administer successfully the new programs under conditions that cannot now be fully foreseen.

"In order that the agency may attract and retain the services of scientists and technicians which it must have to carry out its responsibilities with full effectiveness, it should have the authority, subject to regulations prescribed by the President, to fix the compensation of its employees at rates reasonably competitive with those paid by other employers for comparable work without regard to the provisions of existing classification laws.

"The agency should have the power to conduct research projects in its own facilities or by contract with other qualified organizations. It will thus be free to enlist the skills and resources required for the space program wherever they may be found, and to do so under the arrangements most satisfactory to all concerned."

Cooperation with military. "Provisions should also be made for continuing and further enhancing the close and effective cooperation with the military departments which has characterized the work of the National Advisory Committee for Aeronautics. Under such cooperative arrangements it is expected that the National Aeronautics and Space Agency will perform research required in the furtherance of strictly military aeronautics and space objectives, just as the National Advisory Committee for Aeronautics now carries on important research work for the military services in aerodynamics, propulsion, materials and other fields important to the development of military aircraft and missiles."

NACA's present research. "The National Advisory Committee for Aeronautics is already engaged in research directly related to flight outside the earth's atmosphere and has research facilities adapted to work in space science. Upon the enactment of legislation carrying out my recommendations, all of the resources of the National Advisory Committee for Aeronautics would immediately come under the direction of the new agency."

Programs to be transferred. "The Department of Defense and its contractors, as well as other agencies, have active programs which should be considered for administration by the National Aeronautics and Space Agency. I recommend that this fact be taken into account and provision made for the transfer to the agency of such functions, activities, and facilities of other departments and agencies as may be found to be appropriate for administration by the new agency, subject to the concurrence of the heads of the affected agencies and with the approval of the President.

"The Director of the Bureau of the Budget is transmitting to the Congress draft legislation to establish the National Aeronautics and Space Agency and to authorize research into the problems of flight within and outside the earth's atmosphere. I urge that the Congress give prompt consideration to the draft legislation and that it be enacted at the earliest possible date."

ARPA interim program. "Pending enactment of legislation, it is essential that necessary work relating to space programs be continued without loss of momentum. For this reason I have approved, as part of an interim program of space terminology and exploration, the launching of a number of unmanned space vehicles under the direction of the Advanced Research Projects Agency of the Department of Defense. The projects which I have approved include both scientific earth satellites and programs to explore space. In taking this interim action, I directed the Department of Defense to coordinate these projects with the National Advisory Committee for Aeronautics, the National Science Foundation, and the National Academy of Sciences. I also indicate that when a civilian space agency is created, these projects would be reviewed to determine which should continue under the direction of the Department of Defense and which should be placed under the new agency.

"It is also important that measures be taken to assure the prompt and orderly implementation of the proposed aeronautics and space legislation when enacted. . . ."

Military space research. "It is contemplated that the Department of Defense will continue to be responsible for space activities peculiar to or primarily associated with military weapons systems or military operations. Responsibility for other programs is to be assumed by the new agency. In this connection, I commend to the attention of the Congress the comments of my Science Advisory Committee, in its statement of March 26, 1958, on the military applications of space technology" [*Science* **127**, 803 (11 Apr. 1958)].

NACA to prepare recommendations. "I am also asking the National Advisory Committee for Aeronautics to begin immediate preparation of such detailed plans as may be required to prepare for the assumption by the National Aeronautics and Space Agency of the responsibilities contemplated for it. Those plans are to set forth the specific new space programs to be initiated and are to describe the international organization, management structure, staff, facilities, and funds which will be required. The National Advisory Committee for Aeronautics is to discuss with the National Science Foundation and the National Academy of Sciences the matter of participation by the scientific community in determining the scientific objectives of our space programs. The best scientific judgment available should be utilized. Matters related to dissemination of the data collected should also be considered.

"I have also instructed the National Advisory Committee for Aeronautics to assume the responsibility for preparing and presenting to the appropriate committees of the Congress a full explanation of the proposed legislation and its objectives.

"The vigorous program contemplated will depend not only on adequate legislative authority but also on adequate financial support. I shall shortly submit to the Congress an amendment to the fiscal year 1959 budget to provide funds that will be needed by the new agency in its first year of operation."

Underground Test Error

On 6 March the Atomic Energy Commission issued a report on the underground nuclear shot exploded in Nevada on 19 September. The report contained inaccurate information about the distance at which the test had been detected [*Science* **126**, 200 (2 Aug. 1957)]. The release said "the off-site movement" was slight and the "maximum distance" at which the earth waves of the shock were recorded was about 250 air miles away. In contradiction to this statement, Harold Stassen had told a Senate Disarmament Subcommittee hearing on 28 February that the "very small nuclear shot that was put out underground in last year's test was recorded on every seismic instrument within 1000 miles."

Correction. According to a later explanation by the AEC, "a news correspondent on 7 March called" to check on the distance at which the shot was detected. The correspondent, I. F. Stone, describes in his *Weekly* (17 and 24 March issues) how he checked *New York Times* reports of last September that the test was recorded in Toronto and Rome. He called the Coast and Geodetic Survey and obtained a "list of 19 seismic stations in the U.S. and Canada . . . which are definitely known to have recorded the underground test," and asked the AEC for an explanation.

On 10 March the AEC issued a correction that said: "Seismological stations . . . as far away as College (near Fairbanks), Alaska, about 2320 miles from the shot mesa, recorded the earth waves." Sen. Hubert H. Humphrey, chairman of the Senate Disarmament Subcommittee, stressed the significance of the correction in a statement on 11 March and noted that his subcommittee and "other observers" had brought the error to the AEC's attention. He referred to what Stassen had said about the distance at which the test was detected and commented that the AEC's statements gave "the impression that scientific facts are being used by someone to prove a political point, a dangerous concept to perpetuate in our effort to work out effective arms control agreements."

In a special hearing on 15 March, AEC Commissioner Willard F. Libby explained to the Joint Committee on Atomic Energy that "the error was entirely inadvertent." He repeated this in a letter to Sen. Humphrey dated 12 March and went on to point out that it was not yet clear "whether a non-alerted station hundreds or thousands of miles distant could detect an earth disturbance and identify it as having been caused by a nuclear detonation." Libby explained in his letter that: "When we determined on 10 March that an error had been made, the AEC immediately issued a correction." However, Chairman Durham of the Joint Committee recalled at the 15 March hearing that AEC officials had told the Joint Committee in closed hearings in January that the shot had been recorded in Alaska. The AEC's explanation about how the error occurred in the 6 March release was summarized in the *New York Times* on 16 March.

FAS statement. The Federation of American Scientists' Executive Committee, in a public statement on 20 March, criticized the AEC for failure to provide "complete and frank reporting of the scientific facts which must form the basis for any well informed view on disarmament policy. Decisions on matters of national policy must ultimately rest in the hands of citizens, and it is the duty of responsible officials to ensure that all the relevant facts are made available to the public."

The FAS release noted that "the recent episode does not stand alone." It said the AEC has placed an "optimistic interpretation" on fallout data and that the information it has given to the public in this area has been "incomplete and, by emphasis or omission, misleading." In the case of fallout, as in "the tardy disclosure about the distance of the detection of last September's test explosion, the AEC has been willing to make complete data available only under the pressure of outside scrutiny by non-governmental experts." The committee pointed out that United States agreement to a nuclear test suspension "has undoubtedly been delayed by apprehension in many quarters, growing out of uncertainty regarding the detectability of nuclear weapons tests—even though non-governmental experts have repeatedly stated that a test ban could be adequately inspected with existing techniques.

"The Administration has in the past relied heavily for its advice upon a limited group of scientists in its own employ. . . . It is imperative that in the future the Administration draw upon a more broadly representative group of scientists for its advice, and that scientists not intimately associated with large-scale government programs be included."

AEC lack of candor. A 13-page report, charging that "the AEC's evaluation of the fallout hazard has not been based on the standards of objectivity and candor that are customary in scientific matters," was released on 19 March by the National Committee for a Sane Nuclear Policy. The report quotes extensively from AEC documents to support its contention, analyzing in each case the interpretation placed by the AEC on the scientific data known at the time. The analysis was compiled to demonstrate "that the AEC has . . . tended to foster the most optimistic interpretation (i.e., which most minimizes the expected hazard from fallout radiation) and that the AEC has altered this position only under the pressure of outside scrutiny and attack."

The National Committee for a Sane Nuclear Policy is co-chaired by *Saturday Review* editor Norman Cousins and by Clarence Pickett, long active with the American Friends Service Committee. Present FAS Vice-Chairman Wolfe and former Chairman Charles Price serve with Norman Thomas, Clark Eichelberger, and others on the 16-man Executive Committee. Copies of the report are available from Trevor Thomas, Executive Secretary, NCSNP, 202 E. 44 St., New York 17, N.Y.

Immigration of Professional Workers

Almost 60,000 immigrants classified as professional, technical, and kindred workers entered the United States for permanent residence during fiscal years 1953 through 1956 (July 1952 to June 1956), constituting slightly more than 6 percent of the 900,000 total immigration for those years. Some 12,600 of the professional workers were engineers or natural scientists. The number of the immigrants in the professional group increased annually from 13,000 in 1953 to 19,000 in 1956, although the rate of increase was not as great as that for all immigrants. Only a small proportion, about 7 percent, of all professional workers entered the country with a first-preference quota visa, which is authorized to persons of specialized skills whose services are urgently needed in this country. This information is contained in a report released last month by the National Science Foundation entitled *Immigration of Professional Workers to the United States—1953–1956.*

Engineers constituted the largest occupational segment of the 60,000 in the group of professional immigrants; nurses were second; and teachers of all kinds below college level, third. Physicians and surgeons were fourth, and natural scientists, fifth. The separate occupations of technicians, such as designers, draftsmen, and radio operators, each represented a small proportion of the total, but when counted together outnumbered the teachers.

More than 40 percent of the professional group came directly from Europe in the 4-year period, with the United Kingdom and Germany providing the largest numbers. Canada, however, outnumbered any European country as a source of immigrants in this group, although a large proportion of the Canadian emigrants were not natives of that country. Of the engineers, half came

from Europe, and a fourth from Canada. Among natural scientists, the proportion coming from both Europe and Canada was lower than among engineers. New York, California, and Illinois were the most popular choices of this group as destinations.

Antarctic Meteorological Report

Herfried Hoinkes, an Austrian meteorologist who has been conducting research in the Antarctic as part of the U.S. International Geophysical Year program, reports that although the South Pole receives more sun than any place on earth during December, its midsummer, most of this energy is reflected by the ice cover. Approximately 89 percent of solar energy received in the Antarctic is lost through such reflection. Absorption of radiant heat is slow because of the fine grain of the top layer of snow. This layer is so hard that quite often footprints do not show on it. When prints are left, they remain sharp for weeks, indicating the small amount of evaporation.

Hoinkes made 3664 temperature observations over a 5-month period at the IGY Little America Station. These indicated that under the most common wind conditions, southeasterlies of 19 knots, temperature difference between the surface and 50 feet above was only 1 to 3 degrees. The maximum temperature inversion occurred under clear skies and calm wind conditions because of the strong long-wave radiation from earth to sky. When a cloud cover moves in to block heat loss from the earth and at the same time emit the heat it has collected, a rapid warming of the surface takes place even in winter.

Minimum possible Antarctic temperatures of −108°F have been calculated from observed radiation loss by both Soviet and American meteorologists participating in the IGY program. Actual minimum observation at the U.S. South Pole station in 1957 was −102°F.

Other findings by Hoinkes included an estimate that Antarctic snow dunes move at a rate of 6½ feet an hour, and that moraines of rock and other fill deposited by glaciers are 10,000 years old, compared with hundreds of years for some European and North American moraines, indicating that only very long climatic cycles affect movement of Antarctic glaciers.

Hoinkes is chief glacial meteorologist for the Arctic Institute of North America, which is performing research sponsored by the IGY Committee of the National Academy of Sciences. The IGY Antarctic program in which Hoinkes participated receives logistic support from U.S. Navy Task Force 43, commanded by Admiral George Dufek.

Yale's Heavy Ion Accelerator

A new heavy ion linear accelerator has gone into operation at Yale University. It is accelerating beams of ions of oxygen (oxygen 16) to energies of 160 million electron volts. The first beam was detected on 15 March. Other ions, such as nitrogen, neon, and carbon, can be accelerated in the new facility to energies of 10 million electron volts per nucleon.

Only one other high-energy heavy ion accelerator exists in the United States. This is now in operation at the University of California Radiation Laboratory. These two accelerators were designed jointly by Yale and University of California scientists under the auspices of the Atomic Energy Commission. However, research emphases at the two institutions are different. While the Berkeley scientists are giving priority to chemical transmutation experiments, Yale's emphasis is on the study of nuclear structure.

Director of the Yale project is Edward R. Beringer, professor of physics. He headed a Yale team that began working with University of California scientists in February 1954 to design the two identical linear accelerators.

Tariffs on Instruments

The American Council on Education has endorsed HR 9349 and S 3155, which are intended to remove the tariff barriers on scientific equipment and apparatus for educational institutions. A Council statement reads:

"As a means of assisting American institutions to improve their scientific programs, the Commission on Education and International Affairs (of the A.C.E.) on February 21 gave strong endorsement to the following pending legislation which would permit tax-exempt institutions to import scientific and laboratory apparatus duty free: HR 9349—Congressman Antoni N. Saklak (now under consideration by the Committee on Ways and Means of the House of Representatives); and S 3155—Senator Ralph E. Flanders (now under consideration by the Committee on Finance of the Senate).

"The Commission expressed the conviction that in these critical times when the United States is taking unprecedented steps to further our scientific interests in order to protect our national security and maintain our world standing, every effort should be made to supplement and diversify existing sources of supply of scientific teaching apparatus. The proposed legislation would eliminate the present tariff, on scientific instruments and apparatus imported for educational purposes, of 40 per cent on the average and 50 per cent on optical goods. This tariff prevents many educational institutions from importing specific items which are not readily available domestically."

Scientists in the News

MARGARET MEAD, RAYMOND A. DART, and JAMES B. GRIFFIN have received the 1957 Viking Fund medals of the Wenner-Gren Foundation for Anthropological Research. Mead was selected as the medalist in general anthropology by the American Anthropological Association; Dart was elected by the American Association of Physical Anthropologists as medalist in physical anthropology; and Griffin was the candidate of the Society for American Archaeology for the archeology medal.

Mead, associate curator of ethnology at the American Museum of Natural History and a member of the AAAS board of directors, has done more than any other single individual to introduce anthropology to the American public. Among her most popular books are *Coming of Age in Samoa, Growing Up in New Guinea, Male and Female,* and *New Lives for Old.* Dart, dean of the faculty of medicine at the University of the Witwatersrand, Johannesburg, is recognized as the discoverer of the earliest known human being. Griffin, director of the Museum of Anthropology and professor of anthropology at the University of Michigan, was cited for his great influence in promoting the aims of scientific archeology, and for his knowledge of the form, range, and distribution of artifact styles in North America.

T. E. F. CARR, member of the Medical Research Council's Radiobiological Research Unit at the Atomic Energy Research Establishment, Harwell, England, is visiting the United States till about the end of July. He has been given a leave of absence to take up a temporary appointment with the United Nations for approximately 6 months. He will be in New York first, then he will go to Geneva, Switzerland, to act as biological secretary for the International Conference on the Peaceful Uses of Atomic Energy, 1–13 September.

WILLIAM H. STEWART has been appointed assistant program operations officer of the Public Health Service. He will serve as assistant to ARNOLD KURLANDER, who was recently appointed to the newly created post of Assistant Surgeon General for program operations. Stewart has been an assistant to the Surgeon General for the past 10 months.

SAMUEL J. AJL, assistant chief, department of bacteriology, Walter Reed Army Institute of Research, has received a National Science Foundation senior postdoctoral fellowship for research at the Hebrew University in Jerusalem and at Oxford University, where he will work in the laboratories of Hans A. Krebs. During his stay in Europe, Ajl will attend the International Congress of Microbiology at Stockholm and participate in a symposium on the "Metabolism of C_2 Compound in Microorganisms" convened by Krebs at the International Congress of Biochemistry in Vienna.

WILLIAM F. MAYES has been appointed chief of the Division of General Health Services, Bureau of State Services, of the Public Health Service. He will have special responsibility for programs concerned with research in public health practice and with the training of public health personnel. Before joining the PHS in September 1957, Mayes was associate professor and acting head of the department of public health practice at the Harvard School of Public Health.

Six physicians from the United States and abroad have been named as recipients of Purdue Frederick Medical Achievement Travel Awards for outstanding medical and scientific activities. The awards enable the winners to attend medical meetings of their choice here and in Europe, thereby "furthering the international exchange of medical ideas and information on a physician-to-physician basis."

The two award winners from the United States are both cardiologists at the University of Minnesota: C. W. LILLEHEI of the School of Medicine, and EDGAR V. ALLEN, professor of medicine at the Mayo Foundation Graduate School. The winners from abroad will visit medical research and teaching centers and hospitals here and attend symposiums during April and May. Scheduled to participate in the Fifth International Congress on Internal Medicine in Philadelphia, Pa., are: R. B. HUNTER, department of pharmacology and therapeutics, Queens College, Dundee, Scotland; and HAQVIN MALMROS, professor and director, department of medicine, University of Lund, Sweden.

Recipients planning to attend the World Congress of Gastroenterology in Washington, D.C., are: E. C. FAUST, department of medicine, University of Valle, Cali, Colombia; and ANDRE CHARBONNIER, Paris, of the French National Society of Gastroenterology. Each of the award winners was cited by the Council for active and promising research work in disease treatment and prevention within his medical specialty.

MARCUS M. RHOADES, professor of botany, University of Illinois, Urbana, is delivering this year's Jesup Lectures of the department of zoology, Columbia University. The last two of his six presentations on "The Cytogenetics of Maize" are scheduled for 22 and 24 April.

R. ELSDON-DEW, director of the Amoebiasis Research Unit in Durban, Union of South Africa, has been nominated president-elect of the South African Association for the Advancement of Science for the year 1958–59. He will visit California, Boston, Mass., New Orleans, La., and Washington, D.C., in May 1958.

DONALD O. HEBB, professor of psychology at McGill University, will deliver McGill's annual Hughlings Jackson Memorial Lecture on 14 May at the Montreal Neurological Institute.

ROBERT A. MOORE will be inaugurated as the first president of the State University of New York Downstate Medical Center on 2 May. The ceremony will take place at 2:30 P.M. under a marquee behind the center's Basic Sciences Building at 450 Clarkson Ave., Brooklyn.

ISADORE KATZ, assistant chief of radiology and chief of the x-ray department at the Brooklyn Veterans Administration Hospital, Brooklyn, N.Y., has been named associate professor of radiology at the State University of New York Downstate Medical Center in Brooklyn.

PAUL P. EWALD, professor of physics and retired head of the physics department at the Polytechnic Institute of Brooklyn, has been elected a fellow of the Royal Society (London).

Recent Deaths

DOROTHY L. ASHTON, Philadelphia, Pa., 70; retired professor of gynecology and obstetrics at the Woman's Medical College of Pennsylvania; 19 Mar.

WALTER BARTKY, Chicago, Ill.; 56; vice president in charge of special scientific projects at the University of Chicago; professor of mathematics; 19 Mar.

ERNEST G. BEINHART, Wyndmoor, Pa.; 71; retired in 1957 as tobacco technologist for the U.S. Department of Agriculture and the International Cooperation Administration; 19 Mar.

GEORGE A. BENNET, Philadelphia, Pa.; 53; dean of the Jefferson Medical College since 1950; professor of anatomy and director of the Daniel Baugh Institute of Anatomy since 1948; 27 Feb.

KENNETH S. M. DAVIDSON, Paris, France; 60; engineer and former director of the experimental towing tank at Stevens Institute of Technology; until recently, scientific adviser to Gen. Lauris Norstad, Supreme Allied Commander in Europe; 19 Mar.

FRANCISCO DURAN-REYNALS, New Haven, Conn.; 58; internationally known cancer researcher and faculty member of the Yale University School of Medicine; in 1930 discovered the enzyme hyaluronidase; first to advance the theory that cancer may be caused by viruses; 27 Mar.

LINCOLN ELLISON, Ogden, Utah; chief of the division of Range Management Research, Intermountain Forest and Range Experiment Station; chairman of the Intermountain Section of the Society of American Foresters; chairman of the Western Section of the Ecological Society of America; president of the Utah Academy of Sciences, Arts, and Letters; 9 Mar.

ERNEST H. KUSCH, Tampa, Fla.; 63; psychiatrist at Manhattan State Hospital, New York, for 30 years; lectured at New York University and City College; conducted research in malaria treatment for general paresis and group psychotherapy; 22 Mar.

L. MARY MOUNCH, White Plains, N.Y.; 66; practicing physician and instructor in medicine at the Cornell Medical School in New York; member of the staff at New York Hospital and at White Plains Hospital; former associate and an instructor in medicine at the Mayo Clinic; 27 Mar.

ALBERT G. PARKER, Madison, Ind.; 65; president of Hanover College since 1929 and a Presbyterian minister; in 1919 went to China for 8 years to serve as head of the social science department at Shantung Christian University; 22 Mar.

VICTOR J. PEISSACHOWITZ, Long Island, N.Y.; 72; retired in 1955 as associate professor of chemistry at Long Island University; 24 Mar.

JOHN V. QUARANTA, Blauvelt, N.Y.; 35; chairman of the psychology department at Marymount College, Tarrytown; 23 Mar.

DANIEL P. QUIRING, Cleveland, Ohio; 63; associate professor of biology at Western Reserve University; head of the anatomy department at the Frank E. Bunts Educational Institute; 26 Mar.

CLEMENT STAFF, New York, N.Y.; 47; member of the faculty of the National Psychological Association for Psychoanalysis school and first vice president of the association when it was founded in 1948 by Theodor Reik; author of articles on the social and cultural aspects of psychoanalysis; 25 Mar.

Book Reviews

Oxine and Its Derivatives. vol. I, *Oxine,* pt. 1; vol. II, *Oxine,* pt. 2; vol. III, *Derivatives of Oxine,* pt. 1; vol. IV, *Derivatives of Oxine,* pt. 2. R. G. W. Hollingshead. Butterworths, London, vols. I and II, 1954; vols, III and IV, 1956. 1211 pp. + index. $8.50 per vol.

The first systematic studies of 8-hydroxyquinoline (oxine) and its derivatives were carried out by Berg and his collaborators in the years following 1926. As a result of their work it became apparent that these compounds were important ones for the analysis of a number of inorganic ions. In 1933 Berg published a 30-page monograph devoted to the properties and applications of the oxines. No successor to Berg's monograph has appeared in the ensuing years, and R. G. W. Hollingshead has undertaken the tremendous task of assembling all of the published information now available on this interesting group of compounds. This has proved to be an ambitious undertaking inasmuch as the number of papers and patents on the subject has grown to several thousand.

The author has chosen to be noncritical and detailed in his approach to the problem of presenting the very large mass of information now available about the oxines. As a result, the monograph is very long indeed—four volumes, totaling some twelve hundred pages. Furthermore, it necessarily contains many quotations and data which are contradictory, and the burden of choice of what is significant and what is correct is left, to a considerable extent, in the hands of the reader. The author has done an excellent job of organization, and the chemist should have no difficulty in locating whatever information he needs, despite the length of the work. A good deal of this information is from journals not found in many libraries and in languages with which the chemist may not be familiar.

The first two volumes are devoted exclusively to 8-hydroxyquinoline and include chapters on preparation; physical and chemical properties; application to the separation and determination of the various cations, silica, and phosphate; and, finally, nonanalytical applications of the reagent. In volumes III and IV are found chapters on the preparation, properties, and applications of the rather large number of derivatives of 8-hydroxyquinoline. Volume IV also contains a 37-page chapter on the antibacterial and antifungal action of oxine and of its derivatives and chelates. Nearly half of volume IV is devoted to an addendum of recent papers on the oxines. Most of these papers have appeared since 1953, and the length of this chapter is indicative of the current interest in the subject.

Oxine and Its Derivatives is certainly a valuable reference work and should be a part of the library available to every analytical chemist.

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International Review of Cytology. vol. VI. G. H. Bourne and J. F. Danielli, Eds. Academic Press, New York, 1957. 566 pp. Illus. $12.

Cytology has long since passed the stage of being concerned with purely morphological descriptions of cells; modern cytology attempts to integrate the information obtained in many areas of cellular biology. Viewed in this light, the 12 articles contained in the sixth volume of *International Review of Cytology* fall within the realm of cytology because they deal with studies of single cells, but they should also be of interest to workers in other specialties, such as genetics, virology, embryology, physiology, biochemistry, and histochemistry. Thus, G. H. Beale's description of the genic stability and corresponding cytoplasmic states involved in the antigen system of *Paramecium aurelia* is of interest to the geneticist, immunologist, and embryologist, and the review by R. C. Williams of "The role of the electron microscope in virus research" will concern the virologist as well as the electron microscopist. Three other articles, one by A. Monroy on "An analysis of the process of fertilization and activation of the egg," a second by E. Borghese on "Recent histochemical results of studies on embryos of some birds and mammals," and a third, by R. J. O'Connor, entitled "Carbohydrate metabolism and embryonic determination," are concerned primarily with developmental processes.

The interesting article by A. W. and P. F. Pollister on "The structure of the Golgi apparatus" places the most recent information about this cytoplasmic organelle in its proper perspective with relation to older cytological observations. This historical type of review is extremely valuable at the present time, when modern techniques of electron microscopy and biochemistry have provided a wealth of data which some authors have failed to analyze in terms of the contributions of classical cytology and light microscopy.

Several reviews in this volume deal with a correlation of structure and function. In J. Gross's paper on recent studies of the thyroid, the morphology of the cells and tissue are discussed in relation to glandular activity. In two reviews—one, by G. Siebert and R. M. S. Smellie, on enzymatic and metabolic studies of isolated nuclei and the other, by G. H. Hogeboom, E. L. Kuff, and W. C. Schneider, on recent work in which the combined techniques of homogenization, biochemical assay, and electron microscopy are used—a correlation has been made between cellular constituents and enzymatic activity. The remaining three articles of the volume are of a more specialized nature: "The chromosome cytology of the Ascites tumors of rats, with special reference to the concept of the stemline cell," by S. Makino; "The histochemistry of polysaccharides," by A. J. Hale; and "The kinetics of the penetration of nonelectrolytes into the mammalian erythrocyte," by F. Bowyer.

As a volume, the sixth *International Review of Cytology* lacks cohesiveness of subject matter, owing mainly to the fact that modern cytology covers a very wide variety of interests. All the individual articles adequately summarize the latest information in their particular fields, but those which include speculative and interpretative material are perhaps the most useful for the nonspecialist, who finds it difficult to integrate the voluminous factual data in an unfamiliar field.

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An Introduction to Genetic Statistics. Oscar Kempthorne. Wiley, New York; Chapman & Hall, London, 1957. xvii + 545 pp. $12.75.

The student of biometrical genetics who would like to learn something of the theory on which standard breeding procedures are based has a hard time. The

underlying mathematics is not given in textbooks of animal and plant breeding, while the original literature, stemming largely from R. A. Fisher and Sewall Wright, is notoriously difficult for the uninitiated. This book is an attempt to make some of the theory available in textbook form. It fills a real need and should be a welcome addition to the array of genetics textbooks.

The first part of the book—almost half—is devoted to basic statistical tools for quantitative genetics, including elementary probability, statistical estimation, and hypothesis testing, and some of the elementary theory of population genetics. The rest consists of a systematic statistical treatment of quantitative inheritance. The emphasis is on variance partition, regression and path analysis, inbreeding and correlation between relatives, and Kempthorne's own work on partition of dominance and epistatic components.

Although the introduction states that only high-school algebra is needed, the reader will find that many sections are much more understandable if he is familiar with the calculus and standard statistical procedures. The methods are usually those of the original author, though with added explanation and (especially with Fisher's work) fuller algebraic details.

The book is not without weaknesses. In places the algebra is more cumbersome and lengthy than necessary, and in general the book is repetitious. The explanations are not always clear and are sometimes quite confusing (see, for example, page 303). Also there are occasional slips in algebra, the most troublesome being on page 305, where the subscripts 1 and 2 are interchanged in most of the formulas. Some subjects are dealt with inadequately (for example, human genetics), and it would be preferable, I believe, either to omit them entirely or to do them more completely.

Despite these shortcomings, the book has enough material hitherto unavailable in textbooks to make it uniquely useful for students of biometrical genetics.

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The Ashanti. A proud people. Robert A. Lystad. Rutgers University Press, New Brunswick, N.J., 1958. vii + 212 pp. Illus. $5.

This unpretentious little book will serve the lay reader as a pleasant introduction to the present-day culture of the dominant people of the new state of Ghana. It summarizes, in a simple and painless style, most of the major facts about the social, economic, political, and religious life of the Ashanti nation, with special reference to the town of Goaso, where the author and his wife spent nearly a year in 1949–50. It is entirely authoritative, since the author is a trained anthropologist, an associate professor at Tulane University. Consequently, it should also prove useful to tourists and businessmen who visit Ghana.

In no respect, however, does the volume supplant, or even substantially supplement, the standard ethnographic descriptions of the Ashanti by Busia, Fortes, and Rattray. It is "written down" to about the high-school level of literacy and presents a highly oversimplified account of the culture, with no scientific analysis and extremely little new information. It does not, for example, even mention such complex but scientifically important matters as the famous system of double descent, with both matrilineal and patrilineal clans. Students at the college level will find it much too elementary for use as a text, perhaps even as collateral reading. The professional social scientist, the missionary, and the educated West African will continue to depend upon the earlier sources, and for a summary will use Manoukian's *Akan and Ga-Adangme Peoples of the Gold Coast* (International African Institute, London, 1950).

GEORGE P. MURDOCK
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Reason and Chance in Scientific Discovery. R. Taton. Translated by A. J. Pomerans. Philosophical Library, New York, 1957. 171 pp. Illus. $10.

The history of science, in addition to contributing to what might be called the liberal scientific education, has an undoubted potentiality in providing a record from which scientists can obtain methodological guidance through the experiences of their predecessors. The realization of that potential depends upon an increased cultivation of the field, especially in the more recent period. The product may be something like the present work, which cites and analyzes examples of chance, error, "flashes of thought," and other incidents rare and commonplace in the history of discovery and invention.

This book should interest scientists for the picture that it gives of this product of the history of science. The case histories selected are as various as 16th century astronomy and 20th century medicine, and an interesting attempt is made to correlate them. Unfortunately there are too many cases for the size of the book, and the resultant oversimplification sometimes jars the sensibilities of the historian. Neither scientists nor historians will appreciate the evidences of careless writing, such as the confusion between the terms *discovery* and *invention* (worsened by the translator) and the looseness of the use of the terms *chance, error,* and others.

The original French edition was more modest in format, title, and price.

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Clinical Pathology Data. Compiled by C. J. Dickinson. Thomas, Springfield, Ill., 1957. xviii + 91 pp. $4.

Clinical pathology could be defined as the application of methods and instruments of precision in the diagnosis and follow-up of disease. Physiology, chemistry, physics, microbiology, and immunology are being applied to clinical pathology, in an ever-growing manner. A vast amount of data has accumulated. Only the specialist in this field, the clinical pathologist, is in a position to separate the wheat from the chaff—and to select what is applicable and useful in a particular situation.

The purpose of this book is to classify some of the tests more commonly used in clinical laboratories by giving normal values and the diseases in which the values are raised or lowered. If properly used, the information may save much effort and time that would otherwise have to be spent on trying to find all these things in the library.

The subject matter is treated in 15 sections dealing, respectively, with blood and plasma, cerebrospinal and effusion fluids, feces, gastric contents, porphyrin metabolism, semen, urine, adrenal, pituitary, renal function, hepatic function tests, glucose tolerance test, tests for syphilis, special tests, and some simple procedures (given in brief, practical notes).

The section on blood and plasma has been divided into four subsections, on physical properties, tests of clotting and bleeding disorders, cellular constituents, and chemistry.

Abundant cross references enhance the value of the book.

The accuracy of presentation of the large mass of material is generally satisfactory. Occasional statements could be questioned. The Paul-Bunnell test in a dilution of 1:128 is claimed to be "practically diagnostic of glandular fever" (page 70). This claim is hardly acceptable. Fetal erythroblastosis is treated as synonymous with Rhesus incompatibility of the newborn (pages 12, 19), whereas the part played by the ABO system is referred to as "congenital ABO

incompatibility of the newborn" (page 68). The other responsible blood factors are not mentioned.

Since "biochemical results often differ according to technique used" (page xv), it would have been of some value had mention been made of the methods by which the normal values cited were obtained. This is done only in a few instances.

It is not always clearly stated whether the value given is for whole blood or serum (plasma). Although the modern trend is to report biochemical values on serum, this is not the case in this book (cholesterol, creatinine, glucose nonprotein nitrogen, urea, uric acid).

The conditions which raise or lower *p*H of urine are stated in reverse (page 47). The higher the *p*H, the lower the acidity.

The breakdown of the specific porphyrins is too detailed, since very few laboratories are prepared to analyze for the individual porphyrins.

The statement (page 49) that there are only 2 to 3 milligrams of creatine per 24-hour specimen of adult urine is incorrect.

The statement of normal value (100 percent) for urea clearance (page 59) is misleading; however the discussion tends to correct this. There is no mention made of standard clearance.

No reference to acetone (ketone bodies) in urine was found, except under "Practical analysis."

Although some of the newer tests are included, such as those for transaminase and 5-hydroxyindoleacetic acid in urine, "tubeless" gastric analysis and sweat test for fibrocystic disease of the pancreas are not mentioned.

American readers may be confused by the use of the term *glandular fever*, which has been entirely replaced by *infectious mononucleosis* in this country.

The book can be recommended to medical students and clinical pathologists and to physicians in general as a time- and effort-saving investment.

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Basic Animal Husbandry. John M. Kays. Prentice-Hall, Englewood Cliffs, N.J., 1958. 430 pp. Illus. $7.

A number of new books on animal husbandry have appeared in comparatively recent years, but this is such a changing field and the interests are so varied that the needs have not been exhausted. John M. Kays, the son of an outstanding and colorful author on animal husbandry as well as a noted judge of livestock, is well steeped in livestock lore and its importance in American agriculture.

The interrelationship of judging, breeding, feeding, and management is handled in a concise, logical, and admirable manner. To deal with all classes of livestock in discussing these relationships, as well as with marketing, disease, and parasite prevention and control, is a big assignment. If handled in detail, such a discussion would require a book too voluminous for an ordinary text for a college undergraduate course. However, though the treatment is of necessity brief in some cases, most subjects are handled rather adequately.

The sections dealing with by-products and the marketing of by-products is handled in accordance with the changing times and with the changes in relative values. The chapter on "Common horse unsoundnesses and ailments," though of rather limited use for the farmer of today, should be quite valuable to the light-horseman and the pony fancier.

It appears, in general, that the book has been well prepared, and the pictures are excellent. The author's emphasis on the practical aspects of production and marketing, rather than on the refinements of conformation and breed character (subjects more appropriate to a book on the show ring), is well placed. This book is a welcome addition to the library of the animal husbandman and should be of value to the college and high-school student as well as the layman.

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New Books

Engineering College Research Review. 1957. Engineering College Research Council. American Society for Engineering Education, New York, 1958. 438 pp. $2.

Our Nuclear Future. Facts, dangers, and opportunities. Edward Teller and Albert L. Latter. Criterion Books, New York, 1958. 184 pp. $3.50.

Basic Physics. A. R. Meetham. Pergamon Press, New York, and London, 1957. 155 pp. $3.75.

Algebra. A textbook of determinants, matrices, and algebraic forms. W. L. Ferrar. Oxford University Press, ed. 2, 1957. 228 pp. $2.80.

The Biotic World and Man. Lorus J. Milne and Margery J. Milne. Prentice-Hall, Englewood Cliffs, N.J., ed. 2, 1958. 543 pp. $7.50.

The New India. Progress through democracy. Planning Commission, Government of India. Macmillan, New York, 1958. 422 pp. Cloth, $5; paper, $2.50.

Feedback Control Systems. Otto J. M. Smith. McGraw-Hill, New York, 1958. 712 pp. $13.50.

Communication, Organization, and Science. Jerome Rothstein. Foreword by C. A. Muses. Falcon's Wing Press, Indian Hills, Colo., 1958. 206 pp. $3.50.

The Undiscovered Self. C. G. Jung. Translated from the German by R. F. C. Hull. Little, Brown, Boston, 1957, 1958. 113 pp. $3.

The Metallurgy of Vanadium. William Rostoker. Wiley, New York; Chapman & Hall, London, 1958. 194 pp. $8.50.

The Scientific Papers of Sir Geoffrey Ingram Taylor. vol. I, *Mechanics of Solids.* G. K. Batchelor, Ed. Cambridge University Press, New York, 1958. 603 pp. $14.50.

Growth of Crystals (Rost Kristallov). Reports of the First Conference on Crystal Growth, 5–10 Mar. 1956. English translation (original Russian text published by Academy of Sciences USSR, Moscow, 1957). Consultants Bureau, New York, 1958. 294 pp. $15.

Introductory Physics. An historical approach. Herbert Priestley. Allyn and Bacon, Boston, 1958. 533 pp. $7.50.

Health Facts for College Students. A textbook of individual and community health. Maude Lee Etheredge. Saunders, Philadelphia, ed. 7, 1958. 429 pp.

Advances in Virus Research. vol. V. Kenneth M. Smith and Max A. Lauffer, Eds. Academic Press, New York, 1958. 385 pp. $9.50.

Problems in Euclidean Space: Application of Convexity. Adams Prize Essay of the University of Cambridge, 1955–56. H. G. Eggleston. Pergamon Press, New York and London, 1957. 173 pp. $6.50.

Shackleton and the Antarctic. Margery Fischer and James Fischer. Houghton Mifflin, Boston, 1958. 575 pp. $7.50.

The Fastest Man Alive. Frank K. Everest, Jr., as told to John Guenther. Dutton, New York, 1958. 253 pp. $4.

Antibiotics Annual, 1957–1958. Henry Welch and Felix Marti-Ibanez, Eds. Medical Encyclopedia, New York, 1958. 1087 pp.

Man in the Primitive World, An introduction to anthropology. E. Adamson Hoebel. McGraw-Hill, New York, ed. 2, 1958. 694 pp. $9.

Witchcraft. Geoffrey Parrinder. Penguin Books, Baltimore, 1958. 208 pp. Paper, $0.85.

New Biology. No. 25. M. L. Johnson, Michael Abercrombie, G. E. Fogg, Eds. Penguin Books, Baltimore, 1958. 126 pp. Paper, $0.65.

Le Calcium et la Vie. Joseph Stolkowski. Presses Universitaires de France, Paris, 1958. 126 pp. Paper.

Fantasia Mathematica. Being a set of stories, together with a group of oddments and diversions, all drawn from the universe of mathematics. Clifton Fadiman, Ed. Simon and Schuster, New York, 1958. 317 pp. $4.95.

Purity Control by Thermal Analysis. Proceedings of the International Symposium on Purity Control by Thermal Analysis, Amsterdam, 1957. W. M. Smit. Elsevier, Amsterdam, 1957 (order from Van Nostrand, Princton, N.J.). 194 pp.

Lesser Worlds. Nesta Pain. Coward-McCann, New York, American ed. 1, 1958. 252 pp. $3.75.

Reports

Influence of Sulfhydryl Compounds on Precipitation of Plasma Protein with Ethanol

The use of ethanol to precipitate plasma proteins as the first step in the extraction of free amino acids has disclosed an interesting relationship between the nature of the protein precipitate and the quantity of cysteine in plasma.

When three volumes of 95 percent ethanol are added to plasma from normal individuals, the plasma protein precipitates in a coarse granular form so that the aqueous ethanol supernatant can be rapidly removed by filtration through a sintered glass filter. Plasma from some patients with leukemia, however, has been found to precipitate in such a finely divided state that filtration is difficult. It was thought initially that the striking alteration in the nature of these protein precipitates might be related to changes in the proteins in the patients. This is probably not the case, however, as the following discussion indicates.

It was observed that cysteine was not detectable by paper chromatography in the blood plasma showing this phenomenon. Addition of 2 to 3 μg of cysteine per milliliter of plasma before or after precipitation changed the precipitate to a coarse granular form within a few minutes. Addition of larger amounts of cysteine decreased the time required for conversion of a fine to a coarse precipitate. Low plasma cysteine and altered plasma protein precipitation was observed with blood samples from several patients with chronic lymphocytic leukemia. Patients with acute leukemia and chronic granulocytic leukemia did not show such marked changes from normal. After treatment, marked alterations were observed in many more blood samples from patients with all types of leukemia.

The effect of sulfhydryl compounds was readily demonstrable on human plasma albumin obtained from Cutter Laboratories, Berkeley, Calif. The crystalline material was prepared by a cold ethanol fractionation procedure and was free of preservatives. Albumin dissolved in 0.1*M* phosphate buffer (*p*H 7.4) yielded a fine precipitate with ethanol. The precipitate was changed to a granular one by the addition of cysteine. The time required for this change to take place was dependent upon the concentrations of albumin and cysteine.

After serum albumin was treated at 5°C with performic acid (*1*) to oxidize sulfur to the sulfonic acid level, the change to a more granular precipitate upon the addition of cysteine to the aqueous ethanol suspension was not observed.

Another method for removal of sulfhydryl and sulfide groups was tested. Albumin in 0.1*M* phosphate buffer (*p*H 7.4) was treated at room temperature with excess cysteine (1 mole of albumin to 200 moles of cysteine), and the mixture was allowed to stand for 1½ hours. A twofold excess of N-ethylmaleimide was then added, and the mixture was allowed to stand at room temperature for 1½ hours. The addition of cysteine and N-ethylmaleimide was repeated in the same manner. After dialysis against frequent changes of phosphate buffer (*p*H 7.4) to remove excess reagents, three volumes of ethanol were added. A fine precipitate was obtained that did not show the rapid change expected upon the addition of cysteine.

The findings with ethanol denaturation of plasma proteins are similar to those obtained by others (*2*, *3*) with heat and urea denaturation of plasma proteins. The mechanism proposed by Huggins *et al.* (*3*) to explain the catalytic effect of sulfhydryl compounds upon gel formation with heat and urea can be used to explain the ethanol precipitation phenomenon. It would appear that sulfhydryl compounds catalyze the polymerization of denatured plasma protein by increasing the extent to which intermolecular sulfide bonds are formed, and that the granular precipitates indicate extensive polymerization.

It now appears that the phenomenon of aggregation by the formation of intermolecular disulfide bonds may be associated with the action of many protein precipitants. Two distinctly different mechanisms can lead to this type of polymerization. The sulfhydryl-catalyzed reaction in which intramolecular bonds are broken with the formation of intermolecular bonds can take place anaerobically. Formation of intermolecular disulfide bonds by oxidation of sulfhydryl groups has also been described. The extent of polymerization by either mechanism appears to be determined in part by the number of sulfhydryl and disulfide bonds in the protein and the extent to which the protein precipitant changes the availability of these groups for interaction. Although denaturation may increase the extent of polymerization, it does not appear to be essential for aggregation. Straessle (*4*) has reported that a disulfide dimer of mercaptalbumin is formed without denaturation upon standing in cold aqueous ethanol (72 to 94 percent ethanol by volume). It was suggested that this dimerization may occur by the sulfhydryl-catalyzed type of reaction. Briggs and Wolf (*5*) observed polymerization, apparently without denaturation, by oxidation of soybean protein precipitates.

The polymerization process appears to be faster and more extensive with a protein precipitate. Straessle (*4*) has observed more rapid and complete oxidation of the solid mercury dimer of mercaptalbumin with iodine in aqueous ethanol. Briggs and Wolf (*5*) have observed extensive oxidation of soybean protein by air when precipitation was induced by cooling of the aqueous solution. Sayre and Hill (*6*) have reported polymerization of serum lactic acid dehydrogenase after precipitation with ammonium sulfate. An intermolecular disulfide bond stabilization of fibrin clots has been postulated to involve the sulfhydryl catalyzed type of reaction that follows an initial nonsulfide aggregation of fibrin monomer (*7*). A disulfide polymerization process was found by Deutsch and Morton (*8*) to take place with the globulins from macroglobulinemic serum isolated by precipitation techniques. The importance of the solid phase may lie in the fact that a more favorable orientation of sulfhydryl and disulfide groups is possible. The influence of a solid surface and sulfhydryl orientation on oxidation is illustrated by the work of Callaghan (*9*). Myokinase was found to have two sulfhydryl groups per molecule that underwent oxidation in glass or cellophane tubes that was not observed in plastic tubes or collodion tubes pretreated with hemoglobin.

Disulfide aggregation as discussed above should be clearly differentiated

All technical papers are published in this section. Manuscripts should be typed double-spaced and be submitted in duplicate. In length, they should be limited to the equivalent of 1200 words; this includes the space occupied by illustrative or tabular material, references and notes, and the author(s)' name(s) and affiliation(s). Illustrative material should be limited to one table *or* one figure. All explanatory notes, including acknowledgments and authorization for publication, and literature references are to be numbered consecutively, keyed into the text proper, and placed at the end of the article under the heading "References and Notes." For fuller details see "Suggestions to Contributors" in *Science* 125, 16 (4 Jan. 1957).

from other forms of aggregation that also involve sulfhydryl groups. Hughes (*10*) has described the formation of a mercury dimer of serum albumin, and Madsen, Cori, and Gurd (*11*) have shown an apparently new type of sulfhydryl aggregation of phosphorylase that is prevented by p-chloromercuribenzoate.

Huggins *et al.* (*12*) isolated serum albumin from normal individuals and from patients with malignant disease and found the sulfhydryl content to be the same in each group despite the fact that gel formation of plasma proteins in the latter group was abnormal. It does not appear probable that the plasma proteins from the leukemic patients have an abnormal sulfhydryl content since the ethanol precipitation phenomenon appears to depend upon the plasma nonprotein sulfhydryl level.

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2 February 1958

"Slow" Potential Change in the Atrioventricular Node

Previous considerations of atrioventricular (A-V) conduction have been based on indirect physiological (*1*), clinical (*2*), and pharmacological (*3*) studies, but there has been no direct knowledge of intranodal events. An earlier report from this laboratory indicated the feasibility of recording from the buried portions of the A-V conduction tissue *in situ* (*4*). This technique has furnished some direct evidence about events in the A-V node (*5*).

As a small electrode is moved from the ventricle toward the atrium in the right and left bundles and then into the common bundle, the potential difference between this electrode and a distant point is symmetrical and biphasic, as would be expected in a "cable" of Purkinje fibers (*4*); this activity approaches closer in time to atrial depolarization as the electrode moves nearer to the atrium. The wave consists of a positive deflection (approaching activity), a rapid negative-going deflection (depolarization of cells near the electrode), and a terminal negative portion (receding activity) and appears earliest 30 to 40 msec after the firing of the atrial cells in the A-V nodal region. This discharge precedes the end of the P wave by about 15 msec in the dog. Similar deflections, indicating rapid depolarization of cardiac cells, were never recorded within this 30- to 40-msec interval. There thus existed a "silent" period during which no cellular firing was noted. One report of rapid potentials from the A-V node (*6*) does not place them in this silent period.

In some experiments, a slow potential change was recorded from electrodes in the A-V node during this "silent" period. When studied with direct-coupled amplifiers capable of working close to the theoretical noise limit, this change was found in the A-V node in 16 dogs.

Although many experiments were conducted on the heart *in situ*, examination of this potential required perfusion of the isolated heart, cutting of both conducting bundles, variable frequency stimulation of the sinoatrial node to produce first-degree A-V block, and exact histological localization of each electrode (Fig. 1, I). The apparatus has been described (*7*).

Potentials on an electrode in the mid A-V node are shown in Fig. 1, II. Following a stimulus to the sinoatrial nodal region (*S*), there is a large negative potential, the rapid deflection produced by depolarization of atrial cells in the A-V nodal region. Notches on the upstroke of this potential possibly result from firing of scattered cells in the atrionodal junction. The slow potential follows. It is initially positive, rising above the base line for about 20 msec, and then returns toward the base line. Fig. 1, II, shows changes that occur on increasing the rate of stimulation. The slow potential becomes prolonged, with a longer positive plateau and a long terminal negative phase.

One millimeter downstream (Fig. 1, III *c*), the slow potential has no negative phase; however, the negative-going phase coincides approximately with firing of the common bundle, 1 mm away (Fig. 1, III *b*). The slow potential varies in shape and magnitude, depending on electrode position.

In all studies, the slow potential has prolonged as the atrial stimulation rate has been raised from 2 to 3 per second to 10 per second. Concurrently, the interval between the atrial potential and the common bundle potential increases (Fig. 1, III, IV). At rates near 8 per second, the slow potential exhibits maximum prolongation, and complete (2 to 1) block occurs. During A-V rhythm (Fig. 1, IV), the slow potential precedes all other potentials and usually has a configuration differing from that during sinus rhythm.

The most likely picture of A-V nodal conduction which emerges from our study is the following: Atrial cells in A-V nodal region trigger atrionodal cells. These differ in anatomy from the atrial and the nodal cells (*8*). These cells activate the nodal cells, and the slow poten-

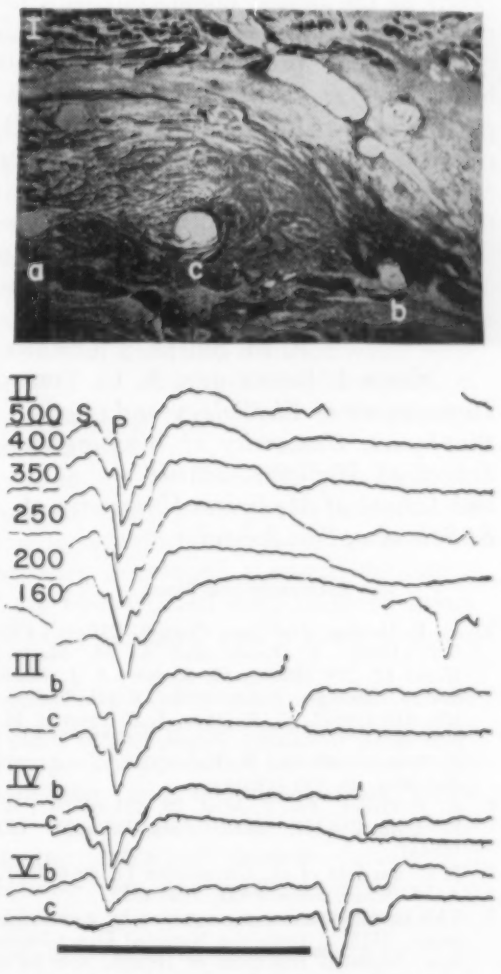

Fig. 1. (I) Histological section through the A-V node, showing locations of recording electrodes in *a*, upper A-V node; *b*, near origin of common bundle; and *c*, intranodal point midway between these. (II) Potentials recorded at point *a*; intervals between stimuli: 500, 400, 320, 250, 200, and 160 msec; *S*, stimulus artifact; *P*, auricular depolarization. At 160 msec, the common bundle did not follow the A-V node and the shape of the atrial potential was altered. The 500-msec record shows ventricular depolarization at the right. Right and left bundles had been cut, and the ventricles beat independently of the atria. (III) Potentials recorded at points *b* and *c* with interstimulus period of 400 msec. (IV) Potentials at *b* and *c* with interstimulus period of 200 msec. (V) Potentials recorded at *b* and *c* during A-V rhythm. (Parts of the auricular complex have been retouched to make the figure clearer.)

tial change propagates through the A-V node. The slow potential, in turn, depolarizes the bundle.

It is apparent from the differences in potential shapes at various nodal sites, and from changes during first degree block, that the slow potential is propagated. Velocity, calculated from measurements of the time of activation of atrial cells in the nodal region, nodal length, and time of bundle activation, range from 0.12 to 0.04 m/sec. It is possible that the lack of rapid deflections from the A-V node results from a difference in the nature of the cellular activity—that is, A-V nodal depolarization involves a slower voltage change than depolarization of other cardiac cells. Study of the buried nodal cells with intracellular electrodes should answer this question, but preliminary experiments have thus far been unsuccessful. Comparison of the slow potential to the end-plate potential seems inappropriate, since (i) retrograde ventriculoatrial excitation is possible; (ii) chemical transmission is probably not involved, as it is in end-plate transmission (*9*); and (iii) the slow potential is propagated.

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16 December 1957

Nutritive Value of Bread Protein Fortified with Amino Acids

Considerable interest has been aroused in the fortification of foods with amino acids and particularly, in view of its quantitative importance, in the fortification of bread with lysine. Several authorities have claimed that large increases in the nutritional value of bread protein result from such fortification, but unfortunately these claims are gross exaggerations.

Table 1. Net protein utilization (NPU) of bread fortified with amino acids.

Item	No. of assays	NPU	± S.E.*
Bread	4	46	± 0.9
Bread + L-lysine (0.2%)	3	57	± 0.9
Bread + L-lysine (0.2%) and DL-threonine (0.88%)	4	70	± 3.2
Bread + L-lysine (0.28%), DL-threonine (1.4%), and DL-methionine (1.1%)	7	79	± 1.4

* S.E., standard error.

The error seems to have arisen from a confusion of the two terms *protein efficiency ratio* (gain in weight per gram of protein eaten) and *biological value* (the percentage of absorbed protein retained by the experimental animal).

Rosenberg and Rohdenburg (*1*) showed that the protein efficiency ratio (PER) of bread protein can be increased from 1.01 to between 1.89 and 2.12 by fortification with lysine. Several authors [Jolliffe (*2*, *3*); Flodin (*4*); Horder, Dodds, and Moran (*5*); and Frazer (*6*)] have misinterpreted this finding as an approximate doubling in the biological value of the protein and even that lysine-fortified bread approaches a biological value of 100. The calculation of Flodin (*7*) that the addition of lysine would add to the individual's diet the equivalent of 27 lb of meat, or 70 qt of milk or 330 eggs is based on the same error.

Protein efficiency ratio is a somewhat imprecise method of measuring nutritive value as it varies with food intake (*8*, *9*). Moreover, a protein efficiency ratio of zero is recorded with protein of which 30 to 40 percent is retained by the animal (*9*, *10*). Biological value or net protein utilization (biological value × digestibility) is independent of food intake and ranges from 0 to 100. Therefore the nutritive value of bread protein that had been fortified with various amino acids was investigated by measuring the net protein utilization (NPU) by the carcass water analysis method of Bender and Miller (*11*).

Sliced loaves were purchased from a grocery shop at a time (1955) when the National Loaf was nominally 80 percent extraction although, in fact, it was considerably lower than this (*12*). The slices were dried in air at 50°C, crumbed, and powdered in a hammer mill. The diet contained 70 percent bread, 15 percent margarine fat, 5 percent potato starch, 5 percent glucose, and an adequate supply of minerals and vitamins (*11*). The amino acid-fortified diets contained the following additives, (i) L-lysine monohydrochloride (0.2 percent lysine); (ii) L-lysine + DL-threonine (0.88 percent); and (iii) L-lysine (0.28 percent) + DL-threonine (1.4 percent) + DL-methionine (1.1 percent). Diets were fed at 1.5 percent nitrogen level for the 10-day experimental period. The results are presented in Table 1.

These results show that, in bread, threonine is the second limiting amino acid and that methionine (or methionine and cystine) is the third. Sure reported (*13*) that threonine was the second limiting amino acid and valine the third in milled wheat flour, and that in whole wheat (*14*) valine was the second and threonine the third. Whether bread, whole wheat, and milled wheat flour do differ in their second and third limiting amino acid is not clearly established.

Rosenberg, Rohdenburg, and Baldini (*15*) concluded that bread containing skim milk solids lacked only lysine. This conclusion was based on two observations: (i) the bread + lysine diet permitted growth equal to that on stock diet, (ii) further supplementation with valine, threonine, and methionine produced no improvement in protein efficiency ratio. The contrary findings in the present paper are not due to the different types of bread used in Great Britain and the United States but to some inadequacy in the diets used by Rosenberg *et al.* who obtained maximum protein efficiency ratios of only 1.8 to 2.4 (corresponding to biological values of 60 to 70) whereas the best protein reaches a protein efficiency of about 4.4 (*9*).

The results shown in Table 1 place in true perspective the increase in nutritional value conferred by the addition of lysine. They agree remarkably well with the values obtained by the method of protein efficiency ratio by Rosenberg and Rohdenburg (*1*) and Hutchinson, Moran, and Pace (*16*, *17*). The protein efficiency ratios found by these authors have been converted into the approximate equivalent of net protein utilization in Table 2 by use of the conversion factor of Block and Mitchell (*10*) and Bender (*9*).

Thus it is clear that all the experimenters are agreed that only about half

Table 2. Comparison of protein evaluations [protein efficiency ratio (PER) and net protein utilization (NPU)] of bread fortified with lysine.

Author	White bread		Bread + lysine	
	PER	Calc. NPU	PER	Calc. NPU
Rosenberg & Rohdenburg (*1*)	1.0	52	1.89	64
Hutchinson, Moran, & Pace (*16*)	1.4	58	2.14	67
Hutchinson, Moran, & Pace (*16*)	0.9	51	1.42	58
Hutchinson, Moran, & Pace (*17*)	1.25	46	2.20	68
Bender (this report)		46		57

of the protein of bread is available for the growing rat and that fortification with lysine increases this to about 60 percent. Flodin's statement (*4*), "there is a latent store of protein in bread and flour that needs only one key to release it for the body's use. That key is lysine fortification" should be amended to at least three keys, lysine, threonine, and methionine.

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5 December 1957

Zinc Requirement of the Chick

Over 20 years ago it was found that the growth of young rats was greatly impaired if their diet was extremely low in zinc. Keratinization of the skin, parakeratosis of the esophagus, loss of hair, and decreased activity of intestinal phosphatase, blood phosphatase, and carbonic anhydrase were later associated with zinc deficiency in the rat (*1*). Zinc has also been shown to be required by the mouse (*2*) and pig (*3*).

Recently, O'Dell and Savage (*4*) reported that the growth of chicks was stimulated if zinc was added to a semipurified diet containing 25 percent of Drackett assay protein C-1. No response to zinc was obtained if casein or alpha protein replaced the Drackett protein or if the level of potassium in the ration was low (*5*). All rations contained about 50 ppm of zinc. The chicks were brooded in batteries which ordinarily are zinc coated, and tap water was supplied, presumably in the galvanized water troughs of the batteries.

We have also studied this problem with chicks (*6*) but have attempted to reduce substantially the amount of zinc ingested. This was done in several ways: (i) selecting ingredients low in zinc; (ii) extracting the zinc from the protein supplement (the source of much of the zinc of the basal ration chosen); (iii) coating the batteries or building nonmetallic pens to prevent contamination with this element; (iv) conducting experiments in isolated quarters to reduce dust as a possible source of zinc; (v) using distilled water instead of tap water; and (vi) providing the drinking water in glass rather than galvanized troughs. All these changes were intended to reduce the amount of zinc ingested by the birds.

In an exploratory experiment, two groups of 5-day-old, White Leghorn cockerels were allocated to pens having plastic mesh sides and rubber mesh floors. The basal diet, similar to that used by Morrison *et al.* (*7*) without the zinc supplement, was fed to one group. This basal diet contained about 16 ppm of zinc. The second group was supplied the basal ration supplemented with 100 ppm of zinc as the sulfate, added by way of the salt premix. The chicks were allowed to eat *ad libitum* in glass feeders, and distilled water was supplied in Pyrex glass waterers.

The group which received the low-zinc, basal diet grew poorly, developed dermatitis of the feet, failed to feather properly, and developed a goose-stepping walk. Symptoms began to appear about the 14th day and were severe by the 21st day. The group fed the zinc-supplemented ration grew satisfactorily during the 4-week test period and did not exhibit any of the symptoms noted in the zinc-deficient group.

On the basis of the results of this preliminary study, a more comprehensive experiment was designed. In this, the Drackett protein was extracted by washing with a hydrochloric acid solution at *p*H 4.6 and then dried about 36 hours in an oven at temperatures up to 100°C. The unextracted basal ration contained 19 ppm of zinc; the extracted basal ration analyzed 7 ppm (*8*). Basal rations containing either the unextracted or extracted protein were fed by themselves and with 100 ppm of zinc as zinc sulfate. A total of 120 White Meteor × White Rock 1-day-old chicks were allotted on the basis of weight into the four groups, each of which contained three replicates of five females and five males each.

The experimental birds were brooded in an electrically heated battery with raised, wire floors. All battery parts were coated with epoxy plastic; the bottoms of the dropping pans and wire floors were coated with shellac. Glass founts having a plastic base supplied distilled water for drinking. The battery was isolated in a room relatively free from dust.

The basal diet was essentially that used by Morrison *et al.* (*7*) without the zinc supplement. Drackett protein was used in basal diet 1; the extracted and dried product was used in basal diet 2. Minerals were reagent-grade chemicals. The experimental diets were mixed in plastic equipment and stored in plastic bags. Experimental diets and distilled water were supplied *ad libitum* throughout the experimental period. Feed consumption was recorded.

Table 1. The effect of zinc deficiency and supplemental zinc on chick weights and feed conversion.

Group	Treatment (diet)	Av. wts* at 4 wk (g)	Gain in wt per lb of feed (lb)
1	Basal 1	183	0.45
2	Basal 1 + 100 ppm zinc	363	0.69
3	Basal 2	101	0.35
4	Basal 2 + 100 ppm zinc	333	0.62

* Significantly different. Orthogonal comparison (*9*). $P < .01$ for groups 1 and 3 versus 2 and 4; group 1 versus group 3; $P < .05$ for group 2 versus group 4.

As shown in Table 1, the birds in groups 1 and 3 grew poorly and utilized their feed inefficiently. As in the previous test, they developed a severe dermatitis of the feet, frizzled wing feathers, infantile body feathers, and a goose-stepping walk.

Addition of 100 ppm of zinc to the ration containing the unextracted protein (group 2) produced normal growth, feathering, and feed utilization. When zinc was added to the ration containing the extracted protein (group 4), response was not quite as good as it had been on the unextracted protein. This difference in performance between groups 2 and 4 shows that some factor(s) in addition to zinc was removed by extraction or that the process of extraction and drying altered the nutritive value of the protein supplement.

The results of these experiments indicate that zinc is required by the chick for growth, feather development, and maintenance of a healthy condition of the skin of the feet as well as for the efficient utilization of feed.

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Demonstration of the 3-Methoxy Analog of Norepinephrine in Man

Recent studies by Armstrong, McMillan, and Shaw (*1*) have shown that a major metabolite of norepinephrine and epinephrine found in human urine is 3-methoxy-4-hydroxymandelic acid. Subsequently it was shown by Axelrod (*2*) that the 3-hydroxy position of both norepinephrine and epinephrine can be methylated by animal tissues to yield the corresponding 3-methoxy analogs. The 3-methoxy analog of epinephrine (ME) was also reported to be present in rat urine (*2*). Since the conversion of catecholamines to their methoxy analogs may play some role in the physiology of these agents, it seemed important to determine whether these substances exist in man.

Table 1. Chromatographic behavior of methoxy analogs of catecholamines and the compound extracted from four pheochromocytomas. Abbreviations correspond to the methoxy analogs of norepinephrine (MN), epinephrine (ME), and 3,4-dihydroxyphenylethylamine (MD). The chromatograms were sprayed for phenols with a freshly prepared solution of N, 2,6-tri-chloro-*p*-quinoneimine (0.05 percent weight/volume in ethanol) followed by borate buffer, *p*H 9.0 (*4*).

Compound	R_f		Color
	Isopropanol-5% NH_3 (8:2)	Butanol-acetic acid-water (8:1:1)	
1	0.62–0.66	0.31	Blue
MN	0.65	0.30	Blue
ME	0.80	0.28	Blue
MD	0.77	0.40	Tan-Pink

Since preliminary attempts to demonstrate the methoxy amines in human urine were unsuccessful, it was decided to look for them in tissues. A human tumor tissue which can be readily obtained and which contains large amounts of the parent catecholamines is pheochromocytoma. When several such tumors were extracted and the extracts subjected to paper chromatography, they were found to contain appreciable quantities of the 3-methoxy analog of norepinephrine (MN).

The tumors (*3*) were homogenized in 6 volumes of 0.01*N* HCl, adjusted to *p*H 10 by addition of a saturated solution of sodium carbonate, and extracted three times with 5 volumes of n-butanol. To the combined butanol extracts were added an equal volume of heptane and 0.2 volume of 0.5*N* HCl. After shaking, the aqueous layer was evaporated to dryness *in vacuo* and the residue taken up in 10 ml of methanol. The methanol was then evaporated to 0.4 ml, and portions were subjected to chromatography on Whatman No. 1 paper with two different solvents. The results of these studies, summarized in Table 1, indicate that all the tumors contained a butanol extractable base (compound 1) identical with MN, as shown by its R_f and the color obtained with the phenol reagent and ninhydrin. In several instances the areas corresponding to MN on the chromatograms obtained with isopropanol-NH_3 were eluted and rechromatographed with butanol-acetic acid. The R_f values obtained were again identical with those of authentic MN. The tumor containing epinephrine was found also to contain two additional phenolic substances, compounds 2 and 3. Compound 2 appeared on the chromatograms between MN and ME and gave a bluish-green color with the phenol reagent, unlike that of the three available standards. Compound 3 exhibited R_f values and color (tan-pink) identical with those of 3,4-dihydroxyphenylethylamine (MD).

The areas on the chromatogram corresponding to compounds 1, 2, and 3 were eluted with 0.01*N* HCl, and their fluorescence characteristics were compared with those of authentic MN, ME, and MD, by means of an Aminco-Bowman spectrophotofluorometer (Fig. 1). All three compounds and the reference standards exhibited maximal activation at 280 mμ and maximal fluorescence at 330 mμ.

Further evidence about the identity of compound 1 was obtained by eluting it from the chromatogram and subjecting it to distribution between equal volumes of 0.5*M* borate buffer, *p*H 10, and n-butanol. Analyses were carried out spectrophotofluorometrically. The distribution coefficients (concn. in butanol/concn. in aqueous) obtained for compound 1 and MN were 0.43 and 0.44, respectively,

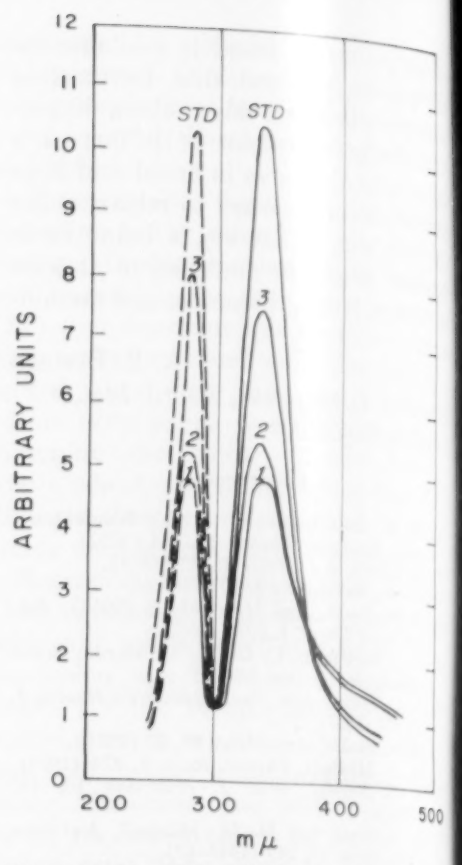

Fig. 1. Activation and fluorescence spectra in 0.01*N* HCl. Compound 1, apparent MN; compound 2, unknown; compound 3, apparent MD, Std., authentic MN; spectra obtained with authentic ME and MD were identical with those of MN.

whereas values for ME and MD were 4.0 and 6.1.

One tumor subjected to quantitative assay for MN by means of a combination of paper chromatography and spectrophotofluorometry was found to contain about 25 μg/g. Preliminary studies indicate that the tumors contain the enzyme which transfers the methyl group from S-adenosylmethionine to the 3-hydroxy group of catecholamines (*5*, *6*).

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5. The 3-methoxy compounds used in these studies were obtained through the generosity of Dr. B. Witkop, National Institute of Arthritis and Metabolic Diseases, National Institutes of Health, Bethesda, Md. The advice of Dr. Julius Axelrod, National Institute of Mental Health, is gratefully acknowledged.
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25 November 1957

Developmental Anomalies in Offspring of Pregnant Mice Treated with Nicotine

It has been known for some time that nicotine is among other things a so-called mitotic poison. Brock *et al.* (*1*) reported that this chemical severely impedes the mitosis of fertilized ovum of the sea urchin, and according to Mainx (*2*) it induces an abnormal mitosis in the epithelium of the oral cavity of the salamander. Although, from a hygienic point of view, the effects of chronic nicotine poisoning on reproduction in the Muridae and on the vitality of the offspring have been studied (*3*), yet no investigation of the effects of nicotine on the development of the offspring has been made. This led us to undertake a detailed investigation of the effects of this chemical on the development of embryos by its transitional application to pregnant mice.

As material, mice of the S strain obtained from the Japanese National Institute of Genetics were used. Female mice 2 to 5 months old were mated, and 230 mice which had been diagnosed as pregnant were used. Between 5 and 15 days after mating, nicotine (0.1 percent aqueous solution) prepared by Merck and Co., Ltd., was injected subcutaneously or intraperitoneally once, or repeated on two or three consecutive days. Most of the animals were sacrificed at term, but some were opened in the period of mid-pregnancy. Then the state of pregnancy and the development of the offspring were investigated; the results are listed in Tables 1 and 2.

As controls, 225 full-term fetuses removed from 29 untreated mice were used; only five cases of resorption were found, and there were no cases with malformations.

Tables 1 and 2 indicate that nicotine, when it is administered during certain periods of pregnancy, has a remarkable lethal effect. In many litters, all the embryos seemed to have died immediately after injection. Sometimes, however, we saw embryos which had developed for a few days after injection and had then died. The litter size of the nicotine-treated mice, whose pregnancy did not undergo complete resorption, was significantly different from that of the controls. Although weights are not listed in the tables, we should note that the average body weights of the surviving embryos were slightly less than those of the control group, but no significant difference was recognized.

Next, it was confirmed that nicotine often showed conspicuous teratogenic effects when it was administered during the mid-term of pregnancy. The effect of three injections given between the 9th and 11th days was more severe than that of one injection given on any other day. Malformations, in almost all cases, belonged to the skeletal system. Defects in the limbs were especially predominant in number. Among them, digits with maldirection were most frequent. Besides the occurrence of the previously mentioned defects, an appreciable number of malformed ankle, elbow, and wrist joints, spinal curvature, and a few cleft palates were observed. It was also shown that the later in gestation the mice were opened, the more anomalies of the limbs were to be observed in the embryos. The critical period for the digital anomalies was assumed to be the 6th to the 14th day. It is to be noted that the highest frequency was recognized in the period from the 7th to the 12th day.

Histologically it was recognized that in the case of a digit with maldirection, its joints were malformed, or bones were deviated. In the case of pes varus or pes valgus, there was an enlargement of the articular cavity in the tibiotarsal joint or an irregularity of the metatarsal bones. In the case of malformed elbow joints, the trochlea humeri was maiformed. In the case of spinal curvature, wedge-shaped vertebral bodies were recognized. Moreover, the over-all osteogenesis was retarded in the bones of the respective joints.

It was also found that in macroscopic or histological observations, placentae of the malformed embryos were normal except in one case in which a fairly large hemorrhagic area was recognized.

Now it must be pointed out that the administration of the chemical before the ninth day of gestation, when the

Table 1. Effects of nicotine (in 0.1 percent aqueous solution) injection on pregnant mice observed at term.

Day of injection	Dosage per day (mg/g) and method of injection*	Total No. of mice	No. of pregnancies undergoing complete resorption	Av. litter size	Fetuses			Type and No. of anomalies†
					Total No.	Dead (%)	Congenital anomalies (%)	
5	0.025 (s.c.)	6	3	4.3	13	0	0	
6	0.025 (s.c.)	17	6	8.1	89	15	9	4T, 3D(t), 1P
7	0.025 (s.c.)	15	5	8.1	81	14	26	2Cu, 7D(f), 8P, 12D(t), 2T
8	0.025 (s.c.)	15	5	7.0	70	17	21	1Cu, 1M, 5P, 10D(t), 3D(f), 1T
9, 10, 11	0.025 (s.c.)	44	23	8.0	168	11	64	9Cu, 4M, 39D(f), 3Sd(f), 1Bd(f), 89D(t), 3Sd(t), 1Pd(t), 36T, 12P
9, 10, 11	0.008 (i.p.)	34	13	7.5	158	15	40	6Cu, 3M, 22D(f), 2Sd(f), 7P, 55D(t), 1Sd(t), 3T
12	0.025 (s.c.)	13	3	6.5	65	32	18	1Cu, 1M, 4D(f), 5P, 5D(t)
13	0.025 (s.c.)	14	3	7.1	78	2	10	4P, 4D(t), 1Ad(t), 1Bd(t)
14	0.025 (s.c.)	10	1	7.2	65	11	11	3Cu, 2D(f), 2P, 3D(t), 2Pd(t)
15	0.025 (s.c.)	14	1	7.4	96	5	0	

* Abbreviations: s.c., subcutaneous; i.p., intraperitoneal.
† Anomalies: Ad(t), adactyly (toe); Bd(f), brachydactyly (finger); Bd(t), brachydactyly (toe); Cu, malformation of elbow joint; D(f), malformation of joint of finger; D(t), malformation of joint of toe; M, malformation in wrist joint; P, malformation in ankle joint (mostly pes varus, occasionally pes valgus); Pd(t), polydactyly (toe); Sd(f), syndactyly (finger); Sd(t), syndactyly (toe); T, spinal curvature.

Table 2. Effects of subcutaneous injection of nicotine (0.1 percent aqueous solution) on pregnant mice observed in the period of mid-pregnancy.

Day of injection	Dosage per day (mg/g)	Total No. of mice	Day sacrificed	Av. litter size	Fetuses			Type and No. of anomalies*
					Total No.	Dead (%)	Congenital anomalies (%)	
8, 9	0.025	6	14	7.3	44	11	2	1T
8, 9	0.025	10	15	6.2	62	5	35	8D(f), 15D(t), 2T, 1He
8, 9	0.025	10	16	8.0	80	6	35	4P, 3D(f), 22D(t), 3Sd(t), 1Sd(f), 3T, 2Bd(t)
8, 9	0.025	7	17	6.7	47	21	41	13D(t), 1Ad(f), 2Bd(f), 1Sd(f), 4T, 1Ps, 1Ba, 1Pa, 1Hu

* Anomalies: Ad(f), adactyly (finger); Ba, shortness of antebrachium; Bd(f), brachydactyly (finger); Bd(t), brachydactyly (toe); D(f), malformation of joint of finger; D(t), malformation of joint of toe; He, hematoma in head region; Hu, umbilical hernia; P, malformation in ankle joint (mostly pes varus, occasionally pes valgus); Pa, eyelids open; Ps, cleft palate; Sd(f), syndactyly (finger); Sd(t), syndactyly (toe); T, spinal curvature.

primordium of the limbs appears, also induces anomalies. For this fact, we are at present not able to give a definite conclusion—that is, the possibility that this chemical affects the cells of the earlier stage than the primordium or that its action continues in the embryo for many days could not be decided. There are many chemical agents, which induce teratogenic effects mainly on the skeletal system, such as nitrogen mustard (*4*), ethylurethan (*5*), 8-azaguanine (*6*), 2,3-dimercaptopropanol (BAL) (*7*). But it is peculiar to the case of nicotine treatment that the critical period for anomalies in limbs is so long and that malformations so often occur in the various joints.

It may be concluded that we confirmed that nicotine has a lethal effect upon embryos of mice and also has a powerful teratogenic effect on their skeletal system when it is administered during pregnancy.

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25 November 1957

Effects of 8-Methoxypsoralen and Ultraviolet Light in Human Skin

Extracts of *Ammi majus* (Linn.) have been used by the Egyptians as pigmenting agents for centuries (*1*). Recently one of the active ingredients of this plant (8-methoxypsoralen) has been publicized by magazines and newspapers as the "sun-tan pill." This substance has been used in the treatment of vitiligo, a disease of human skin in which circumscribed spots of the skin stop forming pigment. 8-Methoxypsoralen has been shown to be a photosensitizer (*2*) but, paradoxically, many individuals have reported that the ingestion of this substance protects them against sunburn (*3*).

The following experiment (*4*) was performed to clarify the mechanism by which 8-methoxypsoralen and sunlight alter the physiological reactions of human skin. The subject (blond, blue-eyed, healthy, 33-year-old white male) exposed an area of the left thigh to ultraviolet irradiation with a mercury vapor lamp at 30 inches distance and with exposure times of 1, 3, 5, 5, 5, 5, 10, 10, 15, 15, 15, 15, and 15 minutes on successive days. Afterward a similar area of the right thigh was exposed in the same manner, but in this second series of irradiations, 20 mg of 8-methoxypsoralen was taken by mouth 2 hours before each exposure. The ultraviolet irradiation was of low intensity, and no clinical redness was produced at any time. Specimens of skin for microscopic examination were removed from the irradiated areas of both thighs on the 7th and 14th days of the irradiation series.

After 14 days of irradiation, the threshold erythema dose of ultraviolet light in the treated area of the left thigh was 25 minutes; 50 minutes of irradiation to the corresponding area of the right thigh produced no redness. Microscopic examination of the specimens of skin revealed that the most prominent change occurred in the horny layer. The horny layer had thickened in both treated areas, but the specimen from the right thigh also revealed the formation of a stratum lucidum. Normally, a stratum lucidum is seen only in areas where the epidermis develops a thick horny layer —for example, on palms and soles. Physiologically, it is never seen in the skin of the thigh. The thickening of the stratum corneum and formation of a stratum lucidum appears to represent the initial reaction of the skin in response to 8-methoxypsoralen and sunlight. There was no melanin present in the stratum corneum in these specimens, so the increased tolerance to ultraviolet light was due solely to the alteration in the horny layer. Miescher (*5*) has shown that ultraviolet irradiation produces thickening of the horny layer; such thickening constitutes the primary protective mechanism of the skin against ultraviolet irradiation.

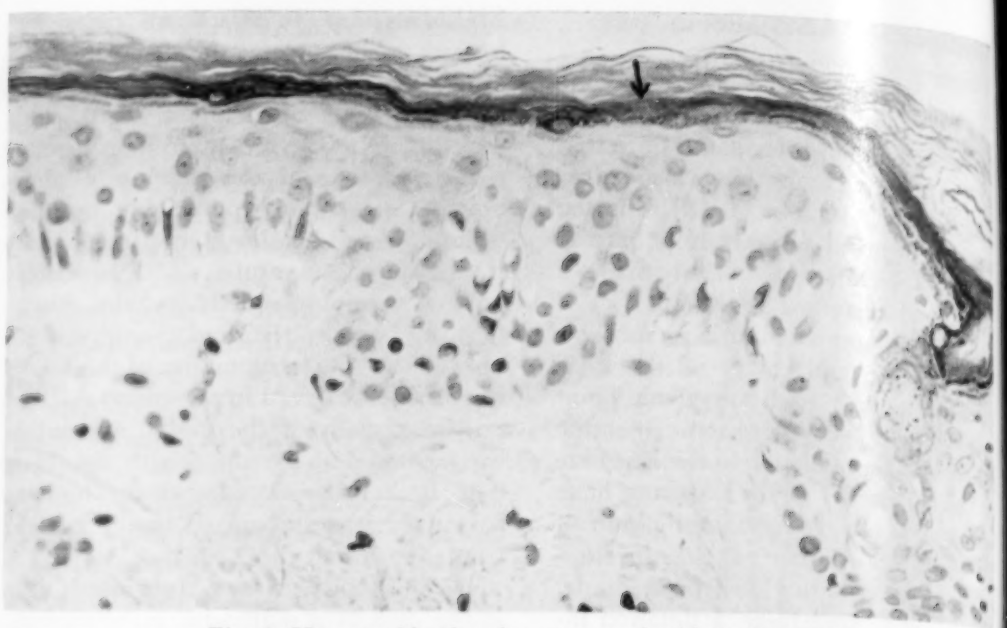

Fig. 1. Human skin showing stratum lucidum (arrow).

Microscopic examination of skin from the back of an individual who had been using 8-methoxypsoralen and sunlight for 2 months revealed a prominent stratum lucidum (Fig. 1.).

The combination of ultraviolet light and 8-methoxypsoralen resulted in more new pigment formation in the treated area of the right thigh than in the corresponding control area of the left thigh. The quantity of newly formed pigment was not great. Examination of the skin from the individual who had used 8-methoxypsoralen for 2 months revealed an abnormally large amount of pigment in both the basal cell layer and the horny layer. The pigment-forming cells and their dendritic processes were not filled with melanin. The absence of pigment in the dendritic processes would indicate that no great amount of pigment was being formed at the time the specimen of skin was removed. It appears from these findings that, while 8-methoxypsoralen increases the pigmenting effect of ultraviolet light, the development of the psoralen tan is due primarily to retention of pigment in the skin. The psoralen tan has a curious quality (*6*), and this may be due to the large amount of melanin retained in the altered horny layer.

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29 November 1957

Cutaneous Vibratory Thresholds for Square-Wave Electrical Pulses

One approach to the understanding of the cutaneous senses is the study of their responses to stimulation by electric currents. If the several senses show different effects of variations in stimulus current parameters, this might help to elucidate the mechanisms involved.

As the frequency of alternating current applied to the skin is increased, there is a rise in thresholds for sensations of vibration (or "tingle") (*1*, *2*) and of pain (*3*), the latter thresholds rising at a somewhat greater rate than the former. These effects could result from such factors as the change in frequency, the change in rate of current increase during an individual cycle, or from the change in duration of each cycle. All these quantities change as the frequency of sinusoidal current is changed, and consequently their effects cannot be assessed separately.

If square-wave stimulation is used, there can be achieved separate variation of frequency and duration, while rate of current increase during each pulse remains constant. Square-wave stimulation is thus a means of analyzing the frequency-intensity functions obtained with sinusoidal currents.

In 1953 Sigel (*4*) published results of stimulation of the upper volar forearm with square-wave electrical currents. It appeared desirable to reinvestigate the matter with several improvements in technique. (i) A stimulator of high impedance was used. Because of the capacitance of the human skin, square-wave voltages applied to it result in the passage through it of currents almost spike-like in form when the source is of low impedance. (The stimulator used by Sigel has an output impedance of 250 ohms.) (ii) The current passed through the skin was measured rather than the voltage applied to it, because of variations in skin impedance during an experimental session. (iii) Psychophysical procedure in threshold measurement was used.

Square waves were provided by a General Radio type 1217-A unit pulser driving a General Radio type 1219 unit pulse amplifier. A 100-kohm potentiometer across the amplifier output provided an adjustable square-wave voltage with which to buck a 45-v cutoff voltage applied to the grid of a type 24-G transmitter triode. The triode plate circuit, operated at 900 v, included in series the subject, a 10-kohm measurement resistance near the electrodes, and 600-kohm of resistance. Current amplitude through the subject was computed from the voltage across the measurement resistance as observed on a DuMont type 340 oscilloscope, calibrated with a DuMont type 264-B voltage calibrator. The diameter of the indifferent electrode was 24 mm; that of the active, positive electrode was 7 mm. Both electrodes were covered with Medcraft electrode paste.

Table 1. Mean absolute thresholds at the several pulse durations and rates. The upper number is threshold in milliamperes; the lower number is the ratio of threshold to mean of all thresholds at 2.0 msec and longer. Entries in parentheses are medians of data from one observer; other entries are means of data from three observers.

Pulses per sec	Pulse duration (msec)							
	0.1	0.2	0.4	0.7	1.0	2.0	4.0	7.0
1000		(1.03)	(0.84)	(0.81)				
		(2.06)	(1.68)	(1.62)				
500	(1.50)	1.25	0.98	0.85	0.85			
	(3.00)	1.88	1.47	1.28	1.28			
200	(1.40)	1.27	0.97	0.78	0.71	0.66		
	(2.80)	1.91	1.46	1.17	1.07	0.99		
100	(1.50)	1.25	0.97	0.79	0.72	0.63	0.67	
	(3.00)	1.88	1.46	1.19	1.08	0.95	1.01	
60	(1.52)	1.37	1.04	0.84	0.75	0.67	0.68	0.69
	(3.04)	2.06	1.56	1.26	1.13	1.01	1.02	1.04

Two graduate students and one staff member served as subjects. All had had previous experience in reporting electrically aroused cutaneous sensations. The seated subject placed the heel of his right palm on the indifferent electrode, his right index finger pad on the active electrode, and was told to report the occurrence of vibratory sensations.

Thresholds were measured by a modified method of limits (continuous variation; ascending series only in order to avoid adaptation). Frequencies investigated were 60, 100, 200, 500, and 1000 pulses per second. Pulse durations ranged from 0.1 to 7.0 msec, with the limitation that a duty ratio of 0.5 could not be much exceeded by the pulse amplifier. The longer durations therefore had to be omitted at the higher frequencies. During a given session on a given day one ascent to threshold was made at each of the 30 usable combinations of frequency and duration. A total of eight sessions, on eight different days, took place for each subject. The presentation order of the frequency-duration combinations was scrambled from one day to another.

The resulting eight measurements at each frequency-duration combination were first averaged for each subject. Before the results for the three subjects were combined, the averages were converted to ratios of the individual's baseline, in order to provide measures which were comparable in spite of individual differences in sensitivity. The baseline for each subject was taken as the mean of his thresholds at durations of 2.0 msec and longer, these values being essentially the same for a given subject. The three baselines were 0.50, 0.69, and 0.80 ma.

Table 1 presents the thresholds obtained in terms of current and also shows the corresponding ratios to baseline, the latter being the dependent variable in the strength-duration curves of Fig. 1. The curves for the several frequencies are quantitatively quite similar, indicating that change of frequency has a negligible effect on electrical vibratory threshold. The pronounced effect of pulse duration on threshold is similar to but somewhat greater than that shown by Sigel for 50 "c.p.s." and is quantitatively similar for the other frequencies investigated.

In the range of frequencies examined, it may be inferred that the increase of cutaneous vibratory thresholds, as sinusoidal current frequency is raised, results largely from the shortening of the half-

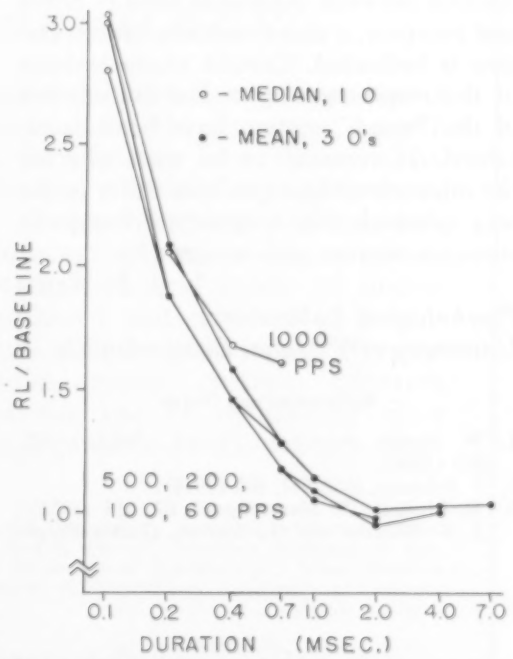

Fig. 1. Strength-duration curves at several pulse rates. "RL/baseline" is the ratio of absolute threshold (RL) to the mean of RL's at pulse durations of 2.0 msec and longer. The parameter is pulses per second (PPS). The means of data from three observers (O's) are indicated by solid circles; at those points for which the RL's of two O's were above maximum stimulator output, the medians of the data for the remaining O are indicated by open circles.

cycle length, rather than from any direct effect of frequency per se. Quantitatively, the effect of halving duration is to double the difference between the absolute threshold and the baseline.

However, it is not clear that duration alone can account for the entire frequency effect in sinusoidal stimulation. At frequencies sufficiently high that the baseline current is a negligible fraction of that required to reach absolute threshold, doubling frequency should double threshold. Schwarz (*2*) found this to occur in the range from 1 kcy to 4–16 kcy/sec (the upper limit depending on certain other parameters), but at higher frequencies (for example, 32 and 64 kcy/sec) thresholds were significantly higher than would be predicted. This might result either from physiological factors such as altered distribution of stimulus current in the tissues, or from increased loss in the stimulating apparatus at high frequencies.

It is of interest that the curves of the present experiment indicate a chronaxie of about 0.2 msec, a value typical of that obtained from A-fibers. Uttal (*5*), reporting an experiment involving the effects of ischemia on thresholds for single electrical pulses applied to the forearm, also concluded that A-fibers were involved in electrical cutaneous sensory stimulation. However, neither experiment necessarily means that "nerve" as opposed to "receptor" is invariably the site of such stimulation. In view of the evidence marshalled by Weddell (*6*) against any necessary morphological distinction between cutaneous sensory nerve and receptor, a more cautious interpretation is indicated. Certain characteristics of the response to electrical stimulation of the "touch" system have been ascertained. It remains to be seen whether the other cutaneous qualities differ in the way in which they respond to changes in stimulus current parameters (*7*).

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21 November 1957

The Molecular Formula Generalized in Terms of Cyclic Elements of Structure

The molecular formulas for all ordinary covalent substances may be generalized in terms of the number of cyclic elements of structure in the molecules according to Eq. 1:

$$\rho = 1 + \tfrac{1}{2} \Sigma n_v (v - 2) \qquad (1)$$

where ρ is the total number of rings and multiple bonds in the molecule (that is, *cyclic structures*), n_v is the number of atoms of covalence v, and the sum is taken over all the v's. The term *cyclic structures* may be used to include both rings and multiple bonds if the latter are considered to be (as they are, indeed, logically, generically, and stereochemically) two-membered rings.

For most organic and inorganic covalent substances, this reduces to Eq. 2:

$$\rho = 1 + \tfrac{1}{2}(2n_{\mathrm{C}} + n_{\mathrm{N,P}} - n_{\mathrm{H},x}) \qquad (2)$$

where n_{C} is the number of carbon atoms in the molecule, $n_{\mathrm{N,P}}$ is the total number of nitrogen and phosphorus atoms, and $n_{\mathrm{H},x}$ is the total number of univalent atoms; hydrogen, halogen, and so forth. The terms for oxygen and any dicovalent element obviously disappear. Equation 2 can, of course, be stated also as

$$\rho = 1 + \tfrac{1}{2}(2n_{\mathrm{IV}} + n_{\mathrm{V}} - n_{\mathrm{I,VII}}),$$

where the subscripts refer to the numbers of the main groups in the Periodic Table.

The single term for all nitrogen atoms regardless of their oxidation numbers or their formal valence numbers follows from the consideration that the cyclic structures containing nitrogen ordinarily involve the three nonpolar bonds and not the additional coordinate bonds present in the higher oxidation state (compare nitroso and nitro groups). Similar considerations apply to the coordinate valencies in oxidized sulfur and phosphorus, but if in these atoms an expanded covalency involving, for example, ten electrons is visualized, the terms $2n_{\mathrm{S}}$ and $3n_{\mathrm{P}}$ would be indicated in Eq. 2.

Electrovalent radicals can be accommodated by reference to their covalent analogs, the free acids and bases; for quaternary nitrogen the term $3n_{\mathrm{N}^+}$ based on an empirical pentavalence, applies.

These equations have practical utility in that the number of cyclic structures is given directly by substituting in Eq. 2 the subscripts in the molecular formula —for example, bromine, $Br_2 = 0$; cholesterol, $C_{27}H_{46}O = 5$; hexamethylene tetramine, $C_6H_{12}N_4 = 3$; nitric acid, $HNO_3 = 1$; nitrogen, $N_2 = 2$; nitroglycerine, $C_3H_5N_3O_6 = 3$; penicillin G, $C_{16}H_{17}N_2O_4SNa = 9$; phosphorus sulfoxide, $P_4O_6S_4 = 3$; phosphorus vapor, $P_4 = 3$; streptomycin, $C_{21}H_{39}O_{12}N_7 = 6$; strychnine, $C_{21}H_{22}N_2O_2 = 12$. It is generally accepted tacitly that in counting the number of cyclic structures in a polycyclic system no cyclic structure is counted if it is made up entirely of elements of other cyclic structures which themselves have been counted. That is, decahydronaphthalene, cyclohexene epoxide, acetylene, and nitrogen contain only two cyclic structures each, and tetrahedral molecules, such as P_4, hexamethylenetetramine, P_4O_6, P_4O_{10}, As_4O_6, and $P_4O_6S_4$, contain only three (not four) cyclic structures.

Equation 2 reduces further to the familiar general formulas for the various homologous series of organic compounds if the restrictions which define the series are introduced into it. For example, for the acyclic saturated hydrocarbons (alkanes, paraffins), introducing $\rho = 0$ and dropping terms other than those for C and H gives $n_{\mathrm{H}} = 2n_{\mathrm{C}} + 2$. Similarly, for the homologous amino monocarboxylic acids, introducing $\rho = 1$ and $n_{\mathrm{N}} = 1$ ($n_{\mathrm{oxygen}} = 2$), gives $n_{\mathrm{H}} = 2n_{\mathrm{C}} + 1$ ($n_{\mathrm{oxygen}} = 2$).

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26 November 1957

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Letters

Science Books for Children

The launching of sputnik I and sputnik II has speeded up the re-evaluation of science education in this country.

For some years now it has been my thought that there ought to be an award for the best science book for young people, similar to the Newberry and Caldecott awards. The John Newberry Medal for the Most Distinguished Contribution to American Literature for Children has been awarded annually since 1922, while the Caldecott Medal has been presented to the artist of the most distinguished picture book of the year.

There is no reason why, in this scientific age of ours—or space age, if you will—the American Association for the Advancement of Science should not make an annual award of a medal, named for an illustrious scientist, in order to single out what the association considers to be the best book on a scientific subject for young children. This would help to develop the idea that the study of science is, after all, part of the study of the humanities; it would help writers of science books; it would help to bring the fields of literature and scientific endeavor together.

It is a truism that our children are the hope of the future. It is they who will be the scientists of the future. I believe, therefore, that establishment of an AAAS science award would be a worthy project, eminently fitting as part of our increased emphasis on science education for the very young. Science education is not only for college and high-school students; it must of necessity begin in the elementary-school grades. I would like to see an award of this type given for books that are published for children below the age of 12. An example of the kind of book that might be honored by such a prize is the beautiful little volume by Irma Eleanor Webber called *Up Above and Down Below*, which is meant for grades two to four in the public schools.

H. Rogosin

Hollywood, California

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Shorthand Notation

In *Science* recently [**127**, 297 (7 Feb. 1958)], H. C. H. Kernkamp describes a method for indicating castration by use of the sex symbols ♀ and ♂ with a portion of the circle removed.

Many laboratories develop a shorthand type of notation to indicate "physiological state." Our own is quite convenient and may be of interest. Castration is indicated by a cross superimposed upon the circle of the gender symbols; immaturity is denoted by incomplete symbols (the female symbol without the crossbar; the male symbol without the arrowhead); pregnancy, by making the vertical bar of the female symbol tangential to the left of the circle, as in the letter *p*; and so on.

Nathan Millman

Ortho Research Foundation, Raritan, New Jersey

"Abominable Snowman"

Recent accounts [*Science* **123**, 1024 (1956); **126**, 858 (1957)] have given various interpretations of the Abominable Snowman or Yeti of the Himalayas. This note on the same subject is directed toward pointing out some aspects of the legend which have been overlooked. The interpretation that tracks in the snow ascribed to the Yeti may be made by man is valid in some instances, but it is clear that footprints cannot logically be attributed to even the most solitary hermit when they are made in remote glaciated terrain at great altitudes where local inhabitants simply would not travel.

The explanation that the Yeti tracks are made by red bears raises a number of difficulties. The footprints, such as those photographed by Eric Shipton in

1951 (*1*), do not resemble bear tracks. Frequently, genuine red bear tracks have been attributed to the Yeti, but when photographs of these tracks have been examined, the bear origin has been clearly established (*2*). Perhaps the greatest difficulty with the bear theory, and the point most often disregarded in statements concerning Yeti tracks, is the fact that the high-altitude red bear of the Himalayas (*Ursus arctos isabellinus*) is found only in the western Himalayas, whereas the origin of the Yeti legend and the source of all "genuine" Yeti tracks is in the eastern Himalayas. There is a fairly striking faunal difference between these two regions, and it is not legitimate, nor is it good zoogeography, to attempt to discredit the legend on evidence obtained from the western Himalayas or the plateau of Tibet. The Abominable Snowman, presumably, has no business in these parts.

Prior to the advent of the eastern Himalayan Sherpas into all sections of the Himalayas as members of expeditions, the mountain peoples from Kashmir to Kumaon had apparently never heard of the Yeti, although they have many other legends. In the eastern Himalayas, from the Everest area through Sikkim, residents of the high valleys continually describe the Yeti (in Sherpa, *ye* means high rocky places; *ti* or *te* or *teh* means a sort of being, perhaps a dwarf but not necessarily a bear) as a bipedal creature with reddish hair, varying in height from four to six feet. Their description fits, in many ways, a bipedal ape, although these people should have no certain knowledge of apes. It is improbable that the Sherpas, who are fine observers and who have a good acquaintance with bears from their frequent travels in Tibet, would repeatedly confuse a bear standing on his hind legs with the Yeti which they describe. Furthermore, in the high valleys of the eastern Himalayas, there are no reports of bears. The forest bear *Selenarctos thibetanus* has not been reported above tree line, much less at 19,000 or 20,000 feet. It is conceivable and possible that the bear of the eastern Tibetan plateau, the so-called blue bear, *Ursus arctos pruinosus,* may occasionally cross over the main crest of the eastern Himalayas, but, if so, this migration has not been reported, and the observant Sherpas deny it. Essentially there is a problem of interpretation involving footprints, which, although they do not resemble bear tracks (and are bipedal over considerable distances, unlike single or overlapping bear tracks), are alleged to be caused by bears in localities where bears are not known to exist.

That the tracks, or at least the sources of the legend, may stem from Himalayan langurs does not seem likely or pertinent. These forest monkeys are well known to

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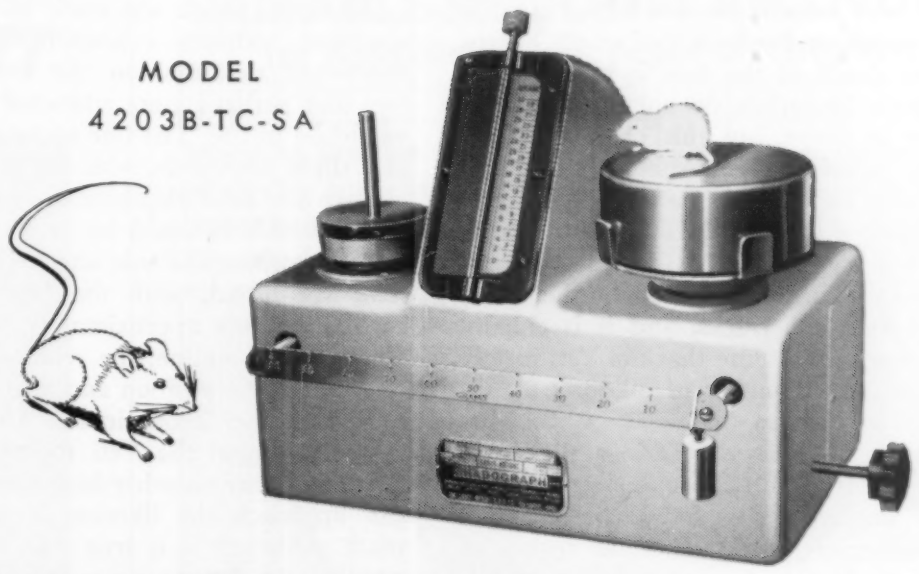

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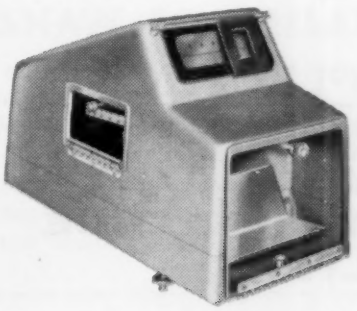

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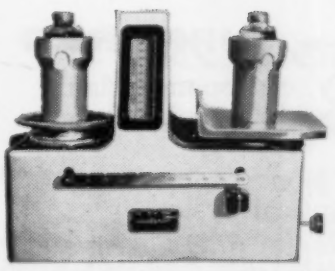

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the mountain peoples, and the Yeti footprints can scarcely be confused with langur tracks. That the unique footprints may be the result of the high-altitude effects of evaporation and sublimation is not borne out by fresh Yeti tracks, where some detail of the foot is clear. High-altitude footprints do enlarge and may alter in shape, but this obvious alteration, which may surprise the casual traveler from the lowlands, is promptly recognized by an individual with experience in snow at high altitudes. It is not correct to assume that only the naive have seen the tracks, and it is equally erroneous to assume that the Yeti is only the imagined maker of all sorts of ablated footprints.

There has been a curious silence in the scientific literature concerning the two unusual scalps found in separate monasteries in the Khumbu region of eastern Nepal. A mammologist of the Zoological Survey of India, Biswamoy Biswas, has examined the scalps, and it has been demonstrated that they are not artifacts (*3*). Photographs of the scalps are quite remarkable in that they indicate a somewhat conical occipital extension, as if the skull possessed prominent temporal and nuchal crests. There is in the scalps the distinct suggestion of a large anthropoid ape. Coincidentally, the footprints photographed by Shipton closely resemble a cast of a foot of the mountain gorilla made by Carl Akeley in East Africa (*4*).

This cast, which was made on a dead specimen, exhibits a prominent hallux somewhat proximal to the remaining toes and perhaps more adducted than it would be in life. The line of toes arches in a slight semicircle, with the fifth digit close to and somewhat beneath the fourth digit, so that it could be inconspicuous in a footprint. The sole and heel of the foot are broad, with the lateral and medial borders approximately parallel. The general outline, the relationship of the hallux, the position and angle of the toes, and the inconspicuous fifth digit strongly suggest the Yeti footprint. Indeed, there are no other footprints which can approach the likeness of the Yeti track. Although it is true that foot impressions in the snow are open to wide subjective interpretation, it would seem to be a conservative assumption that the Yeti track, as it appears in good photographs, resembles Akeley's gorilla cast much more than it does any normal footprint of a bear.

In addition, there are reports of reversed "knuckle" prints such as might be made by an ape and, in fact, there are all sorts of tenuous indications from various Yeti tracks which can be interpreted to point toward the ape origin of the footprints. Among the apes, the mountain gorilla sometimes inhabits relatively high altitudes (its presence on snow fields has been recorded) in an alpine ecological zone not unlike that found in the Himalayas. The zoogeographical status of the eastern Himalayas as an area where relictual genera are frequent suggests that the existence of a relictual high-altitude ape with relatives in the tropics of Africa and Southern Asia is not an illogical supposition. Similar distributions are found among other mammal groups which at one time were widespread in Asia.

Whereas it is perhaps presumptuous to assume, at this time, that the Yeti is in reality some large anthropoid ape, it seems that this possibility has not been eliminated or sufficiently considered in the current arguments of the Yeti critics.

LAWRENCE W. SWAN
San Francisco State College, San Francisco, California

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2. F. S. Smythe, *The Valley of Flowers* (Norton, New York, 1949), pp. 150–151; M. S. Mani, "The abominable snow-man," *Turtox News* 35, 172 (August 1957).
3. *The Statesman, Calcutta* (4 March 1954 *et seq.*); R. Izzard, "The abominable snowman" (Doubleday, New York, 1955).
4. C. Akeley, "Gorillas—Real & Mythical," *J. Am. Museum Nat. Hist.* 23, 433 (1923).

I certainly have never denied the possibility of the existence of an "abominable snowman," whether it be a giant ape or some other unknown creature. I am only adhering to a basic tenet of scientific procedure when I ask for something in the way of positive proof of its reality. Unfortunately, those who claim to have seen the "snowman" seem never to have a rifle at hand, nor even a camera. Inference and argument are entertaining and admittedly suggestive; but the real proof of the pudding is in the eating thereof. Collateral evidence, such as footprints, is subject to diverse interpretations. In this connection, I cannot help but recall the "orang pendek" and the "Loch Ness monster." If someone supplies me with the cadaver of an undoubted "snowman," I will be only too glad to dissect it and report, to the best of my ability, on the creature's zoological affinities. Until such proof of its existence, or other proof which is just as convincing, is at hand, I reserve the right to be skeptical. Of particular pertinence in this instance is the observation of W. K. Brooks that "suspended judgment is the greatest triumph of intellectual discipline."

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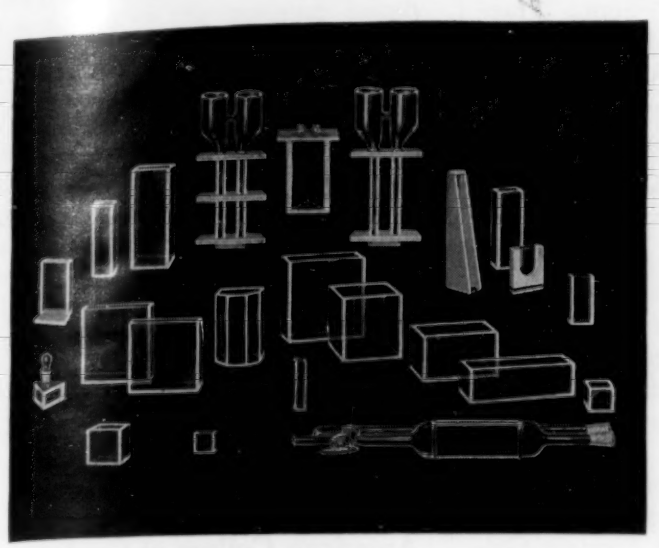

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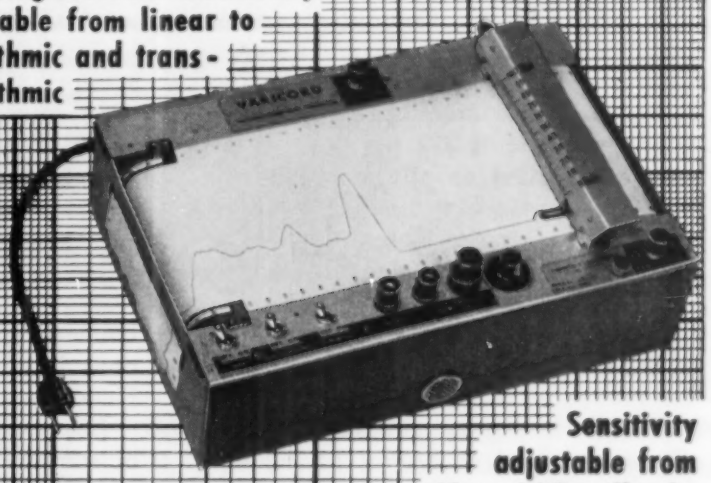

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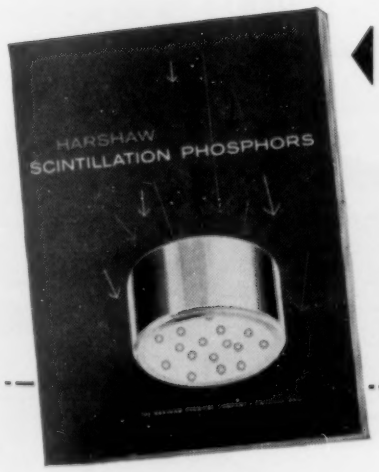

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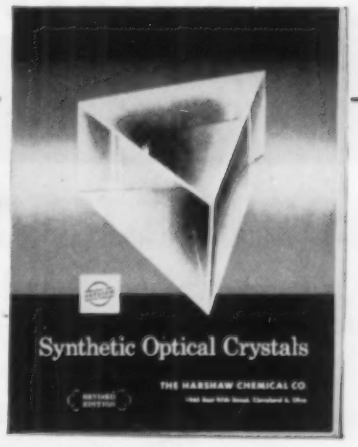

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Meetings

Laurentian Hormone Conference

The 1958 Laurentian Hormone Conference of the AAAS will be held at Blaney Park Resort, Blaney Park, Mich., 7–12 September. Investigators interested in attending this conference should make application to the Committee on Arrangements of the Laurentian Hormone Conference, 222 Maple Ave., Shrewsbury, Mass., *no later than 12 May*. A conference rate of $12 per day per person is extended to all invited participants. Attendance is limited to invitations issued by the Committee on Arrangements. The following program has been arranged:

The Pituitary Hormones: "The physiology of growth hormone with particular reference to its action in the rhesus monkey," E. Knobil and R. O. Greep, Harvard School of Dental Medicine, 7 Sept.; "Human growth hormone," Maurice S. Raben, New England Center Hospital, 8 Sept.; "Studies on the isolation and properties of the follicle stimulating hormone," Sanford L. Steelman and Albert Segaloff, M. D. Anderson Hospital and Ochsner Foundation, 8 Sept.; "Control by visible light of the gonadotrophic activity of the hypophysis in the domestic duck," Jacques Benoit and Ivan Assenmacher, College de France, 8 Sept.

Aspects of Steroid Chemistry and Metabolism: "Steroid protein conjugates," Seymour Lieberman, Bernard F. Erlanger, Sam Beiser, and F. J. Agate, Jr., Columbia University, 9 Sept.; "Fractionation and isolation of steroid conjugates," John J. Schneider and Marvin L. Lewbart, Jefferson Medical College, 9 Sept.; "The miscible pool and turnover rate of adrenocortical steroids," Ralph Peterson, National Institutes of Health, 9 Sept.

Aldosterone Chemistry and Physiology: "The physiological factors which influence the secretion of aldosterone," Gordon L. Farrell, Western Reserve University, 10 Sept.; "Aldsoterone functions in man," F. C. Bartter, National Heart Institute, 10 Sept.

Hormones and Metabolism: "Effects of steroids on metabolism of lymphoid tissue," A. White, Albert Einstein College of Medicine, 11 Sept.; "Central nervous system factors in the regulation of endocrine secretion," John W. Mason, Walter Reed Army Medical Center, 11 Sept.; "Recent studies on secretin and cholecystokinin," Erik Jorpes and Viktor Mutt, Karolinska Institute, 11 Sept.; "The parathyroids and regulation of blood calcium," Harold Copp, University of British Columbia, 12 Sept.; "Endocrine interrelationships influencing bone formation and bone resorption in birds," Marshall R. Urist, University of California Medical Center, Los Angeles, 12 Sept.

Australasian Radiation Biology

The second Australasian Conference in Radiation Biology will be held at the Cancer Institute, Melbourne, Australia, 15–19 December. Papers on relevant subjects are invited. Titles and a 250-word abstract should be received *by 31 July*. Further information may be obtained from the convener, Dr. J. H. Martin, Physics Department, Cancer Institute Board, 483 Lt. Lonsdale St., Melbourne, Victoria, Australia.

American College of Cardiology

The American College of Cardiology will hold its seventh annual meeting at the Chase–Park Plaza Hotel in St. Louis, Mo., on 20–24 May. The general topic will be "Metabolism of the Heart in Health and Disease." The scientific pro-

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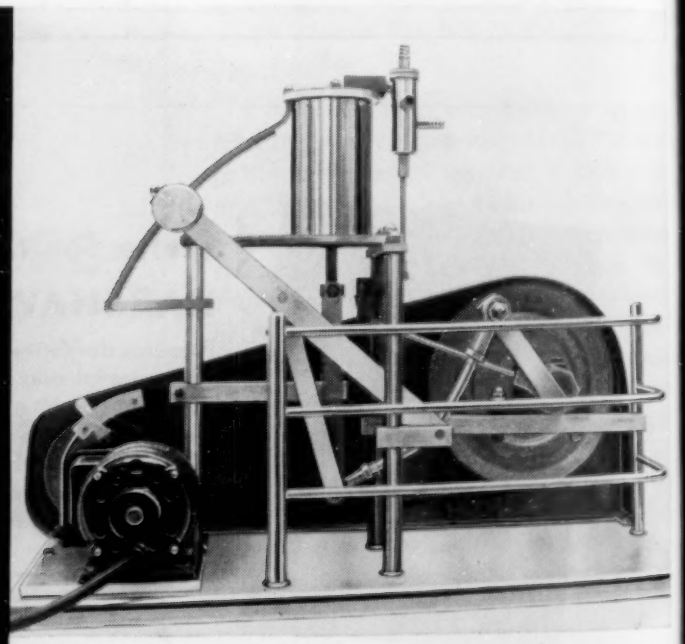

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gram will consist of symposia, panel discussions, fireside conferences, and lectures on clinical and basic research in cardiac metabolism, with particular emphasis on cardiac hypertrophy and the effects of exercise and physical stress on cardiac function.

George R. Meneely, Nashville, Tenn., will preside over the meeting jointly with John S. La Due, chairman of the scientific program; Seymour Fiske, general chairman; and Edward Massie, chairman in charge of local arrangements. The program may be obtained from Dr. P. Reichert, Secretary, Empire State Bldg., New York 1, N.Y.

Scientific Study of Sex

The Society for the Scientific Study of Sex will hold its first annual meeting on 8 November at the Barbizon-Plaza Hotel in New York. For details write Robert V. Sherwin, 1 E. 40 St., New York 17, N.Y.

The society has been organized to foster interdisciplinary exchange in the field of sexual knowledge. The aim of the society is to bring together scientists working in the biological, medical, anthropological, psychological, sociological, and allied fields who are conducting significant sexual research or whose profession confronts them with sexual problems.

The SSSS will hold periodic scientific meetings for the presentation of research papers. It will organize symposia, seminars, workshops, conferences, and so forth, to consider theoretical and practical problems in the sexual area. It will also publish a journal devoted to relevant original studies and reports.

Membership requirements are as follows: for fellow, a doctor's degree or its equivalent in one of the biological or social sciences, plus outstanding contributions to sexual knowledge; for members, a graduate degree or its equivalent in one of the biological or social sciences plus contributions to sexual science—or significant contributions to sexual science. Further information concerning the society and its activities may be obtained from R. V. Sherwin.

Canadian High Polymer Forum

The eighth Canadian High Polymer Forum is to be held 12–14 May at MacDonald College, Quebec. On 12 May the guest speaker, Professor Gee of the University of Manchester, will address the forum banquet on "Predicting Polymer Properties." Reservations for accommodation in the college dormitories are now being accepted by Dr. E. B. Bagley, Central Research Laboratory, Canadian Industries Limited, McMasterville, Que-

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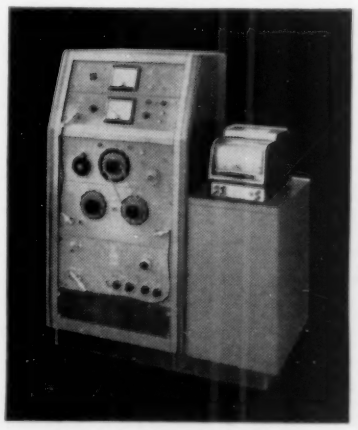

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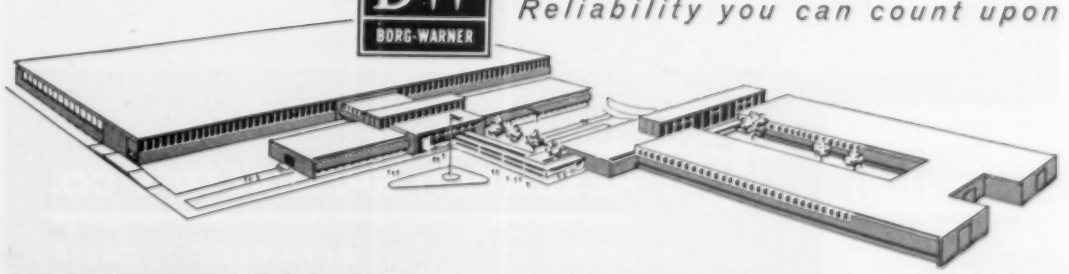

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■ Society for Experimental Stress Analysis: pres., E. Wenk, Jr., Southwest Research Institute; sec.-treas., W. M. Murray, Massachusetts Institute of Technology, Cambridge, Mass. The vice presidents are W. R. Campbell, General Electric Company, and B. J. Lazan, University of Minnesota. The representative to the AAAS Council is Miklos Hetenyl, Northwestern University.

■ Society for Industrial and Applied Mathematics: pres., Thomas H. Southard; sec., Donald B. Houghton, 294 Western Way, Princeton, N.J.; assistant sec., T. N. E. Greville; treas., Robert J. Bickel. The vice presidents are Brockway McMillan and Donald L. Thomsen, Jr. The representative to the AAAS Council is Mina Rees.

■ Tennessee Academy of Science: past pres., Isabel H. Tipton, Department of Physics, University of Tennessee; pres., Arlo I. Smith, Department of Biology, Southwestern University; pres.-elect, Robert T. Lagemann, Department of Physics, Vanderbilt University; sec., Wendell G. Holladay, Department of Physics, Vanderbilt University, Nashville, Tenn.; treas., Harris J. Dark, Department of Mathematics, Middle Tennessee State College. The representative to the AAAS Council is Clinton L. Baker, Department of Biology, Southwestern University, Tenn.

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■ American Society of Criminology: pres., John P. Kenney, University of Southern California; sec.-treas., William Dienstein, Fresno State College, Fresno 26, Calif. The vice presidents are Clyde B. Vedder, University of Arizona; Richard A. Myren, Department of Police Administration, Indiana University; Vernon Fox, Florida State University; and Donal E. J. MacNamara, New York Institute of Criminology, who is also representative to the AAAS Council.

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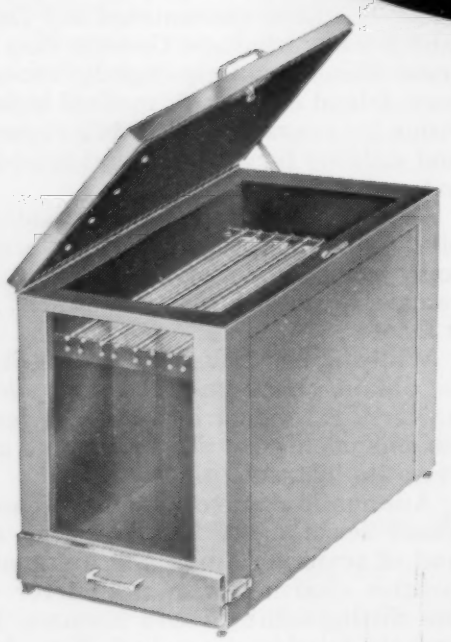

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8. Association of Vitamin Chemists, Chicago, Ill. (A. E. Denton, Research Labs., Swift & Co., Chicago 9.)

8–9. Colorado-Wyoming Acad. of Science, annual, Denver, Colo. (R. G. Beidleman, Zoology Dept., Colorado College, Colorado Springs.)

8–10. Illinois State Academy of Science, 51st annual, Urbana. (R. A. Evers, Illinois Natural History Survey, Urbana.)

11–16. Social Welfare, natl. conf., Chicago, Ill. (National Conf. on Social Welfare, 22 W. Gay St., Columbus 15, Ohio.

12–14. High Polymer Forum, 8th Canadian, Ste. Anne de Bellevue, Quebec. (M. H. Jones, Dept. of Chemistry, Ontario Research Foundation, 43 Queens Park, Toronto 5, Ont.)

12–14. Instrumental Methods of Analysis, internatl. Symp., Houston, Tex. (H. S. Kindler, Instrument Soc. of America, 313 Sixth Ave., Pittsburgh, Pa.)

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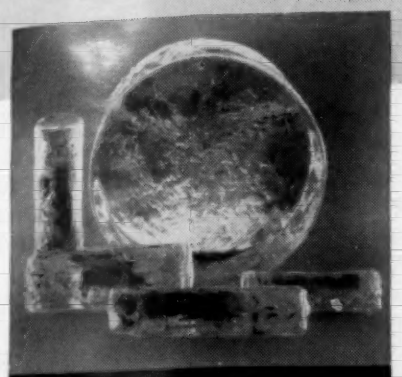

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12–14. Research Methods and Instrumentation Symp., 8th annual, Bethesda, Md. (J. B. Davis, National Institutes of Health, Bethesda 14.)

12–16. American Psychiatric Assoc., annual, San Francisco, Calif. (D. Blain, APA, 1785 Massachusetts Ave., NW, Washington 6.)

14. American Acad. of Arts and Sciences, Brookline, Mass. (R. W. Burhoe, 280 Newton St., Brookline 46.)

14–16. Society for Experimental Stress Analysis, Cleveland, Ohio. (W. M. Murray, P.O. Box 168, Cambridge 39, Mass.)

14–24. European Acad. of Allergy, The Hague, Netherlands. (EAA, 17 Emmalaan, Utrecht, Netherlands.)

15–16. Operations Research Soc. of America, Boston, Mass. (M. L. Ernst, Box 2176, Potomac Station, Alexandria, Va.)

15–17. Basal Ganglia Surgery for Involuntary Movement Disorders, symp., New York. (Miss D. P. Frome, Office of Public Relations, New York University-Bellevue Medical Center, 550 First Ave., New York 16.)

18–24. Sanitary Engineering, 6th Inter-American Cong., San Juan, Puerot Rico. (E. Ortega, Box 218, San Juan.)

19–21. American Trudeau Soc., 53rd annual, Philadelphia, Pa. (K. R. Boucot, Woman's Medical College, Philadelphia.)

19–23. Gas Chromatography, 2nd symp., Amsterdam, Netherlands. (G. Dijkstra, Postbox 114, Vlaardingen, Netherlands.)

20–22. Biosynthesis of Terpenes and Sterols, Ciba Foundation symp. (by invitation), London, England. (G. E. W. Wolstenholm, 41 Porltand Pl., London, W.1.)

20–24. American College of Cardiology, 7th annual, St. Louis, Mo. (P. Reichert, ACC, Empire State Bldg., New York 1.)

25–29. Air Pollution Control Assoc., 51st annual, Philadelphia, Pa. (H. M. Pier, APCA, 4400 Fifth Ave., Pittsburgh.)

25–29. Institute of Food Technologists, annual, Chicago, Ill. (C. S. Lawrence, IFT, 176 W. Adams St., Chicago 3.)

25–31. International Soc. of Gastroenterology, 3rd world cong., Washington, D.C. (H. M. Pollard, University Hospital, Ann Arbor, Mich.)

26–28. American Soc. for Quality Control, annual, Boston, Mass. (W. P. Youngclaus, Jr., ASQC, 161 W. Wisconsin Ave., Milwaukee 3, Wis.)

26–29. Comparative Endocrinology Symp., Cold Spring Harbor, N.Y. (Symposium of Comparative Endocrinology, Dept. of Zoology, Columbia Univ., New York 27.)

27–31. Thermal and Hydraulic Power Stations, Liége, Belgium. (A. Biron, 1, rue de Spa, Liége.)

28–8. European Federation of Chemical Engineering, 2nd cong., Brussels, Belgium and Frankfurt/Main, Germany. (Deutsche Gesellschaft für Chemisches Apparatewesen, Rheingau-Allee 25, Frankfurt/Main.)

29–31. American Acad. of Dental Medicine, 12th annual, Montreal, Canada. (G. Witkin, AADM, 45 S. Broadway, Yonkers 2, N.Y.)

31–8. European Federation of Corrosion, 2nd cong., Frankfurt/Main, Germany. (Gesellschaft Deutscher Chemiker, Haus der Chemie, Karlstrasse 21, Frankfurt/Main.)

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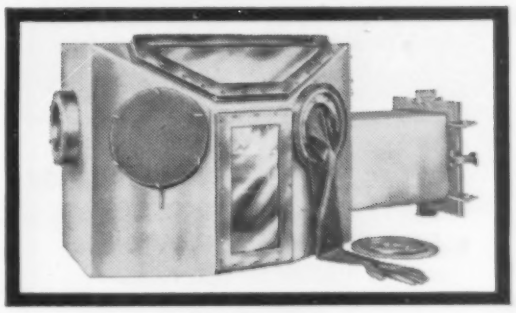

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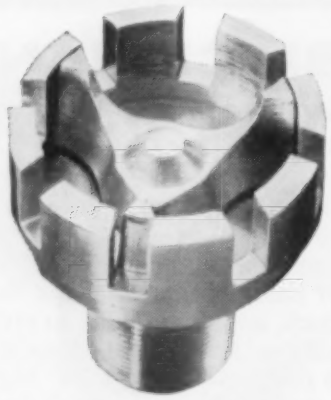

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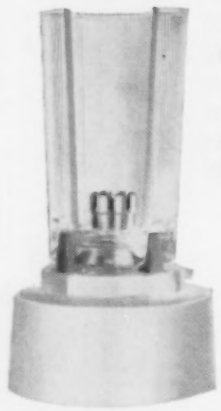

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2–4. Telemetering Conf., 6th natl., Baltimore, Md. (G. M. Thynell, Applied Physics Lab., Johns Hopkins Univ., Silver Spring, Md.)

2–5. American Nuclear Soc., 4th annual, Los Angeles, Calif. (ANS, P.O. Box 963, Oak Ridge, Tenn.)

2–6. Mass Spectrometry, 6th meeting, New Orleans, La. (R. A. Friedel, U.S. Bureau of Mines, 4800 Forbes St., Pittsburgh 13, Pa.)

2–6. Medical Library Assoc., 57th annual, Rochester, Minn. (T. E. Keys, Librarian, Mayo Clinic, Rochester.)

2–6. Peaceful Uses of Atomic Energy in Australia, symp., Sydney, N.S.W. (Australian Atomic Energy Commission Research Establishment, Private Mail Bag, Sutherland, New South Wales.)

2–7. Mechanical Engineering, 7th internatl. cong., Scheveningen, Netherlands. (International Mechanical Engineering Cong., 10, avenue Hoche, Paris 8°, France.)

8–12. Special Libraries Assoc., annual, Chicago, Ill. (M. E. Lucius, SLA, 31 E. 10 St., New York 3.)

9–11. American Assoc. of Spectrographers, 9th annual symp., Chicago, Ill. (H. J. Hettel, Armour Research Foundation, 10 W. 35 St., Chicago 16.)

9–11. Canadian Federation of Biological Societies, 1st annual; with Canadian Assoc. of Anatomists, Canadian Biochemical Soc., Canadian Physiological Soc., and Pharmacological Soc. of Canada; Kingston, Ontario. (E. H. Bensley, Montreal General Hospital, 1650 Cedar Ave., Montreal 25, P.Q.)

9–11. Health Physics Soc., 3rd annual, Berkeley, Calif. (E. E. Anderson, Oak Ridge National Lab., Oak Ridge, Tenn.)

9–11. Soc. of General Physiologists, Woods Hole, Mass. (F. G. Sherman, Dept. of Biology, Brown Univ., Providence 12, R.I.)

9–12. Microscopy Symposium, 5th, Chicago, Ill. (W. C. McCrone, Jr., 500 E. 33 St., Chicago 16.)

9–13. Automation Exposition and Cong., 4th Internatl., New York. (International Automation Exposition, c/o Richard Rimbach Assoc., 845 Ridge Ave., Pittsburgh 12, Pa.)

10–12. Astronomical Soc. of the Pacific, annual, Los Angeles, Calif. (S. Einarsson, Leuschner Observatory, Univ. of California, Berkeley 4.)

10–13. Vacuum Techniques, 1st internatl. congress, Namur, Belgium. (E. Thomas, c/o CSN/ERM, 30, avenue de la Renaissance, Brussels 4, Belgium.)

11–14. Applied Mechanics, 3rd natl. Cong., Providence, R.I. (W. Prager, Brown Univ., Providence 12.)

11–14. National Soc. of Professional Engineers, St. Louis, Mo. (P. H. Robbins, NSPE, 2029 K St., NW, Washington, D.C.)

14–21. American Soc. of Medical Technologists, annual, Milwaukee, Wis. (Miss R. Matthaei, Suite 25, Hermann Professional Bldg., Houston 25, Tex.)

15–19. American Soc. of Mechanical Engineers, semiannual, Detroit, Mich. (O. B. Schier, II, ASME, 29 W. 39 St., New York 18.)

15–19. Cancer Research Conf., 3rd Canadian, Honey Harbour, Ontario. (R. L. Noble, Collip Medical Research Lab., Univ. of Western Ontario, London, Ont., Canada.)

15–20. American Physical Therapy Assoc., annual, Seattle, Wash. (Miss M. E. Haskell, APTA, 1790 Broadway, New York 19.)

16–18. Military Electronics Conv., 2nd, Washington, D.C. (G. Rappaport, Emerson Radio & Phonograph Corp., 1140 East-West Highway, Silver Spring, Md.)

16–18. Photochemical Apparatus Symp., Upton, N.Y. (R. C. Fuller, Biology Dept., Brookhaven National Laboratory, Upton, L.I.)

16–20. American Soc. for Engineering Education, annual, Berkeley, Calif. (W. L. Collins, Univ. of Illinois, Urbana.)

16–20. Association of Official Seed Analysts, annual, Montreal, Quebec, Canada. (L. C. Shenberger, Seed Lab., Dept. of Agricultural Chemistry, Purdue Univ., Lafayette, Ind.)

16–20. Molecular Structure and Spectroscopy Symp., Columbus, Ohio. (R. A. Oetjen, Dept. of Physics and Astronomy, Ohio State Univ., Columbus 10.)

16–20. Pacific Div., AAAS, annual, Logan, Utah. (R. C. Miller, California Acad. of Sciences, Golden Gate Park, San Francisco 18.)

17–19. American Dairy Science Assoc., annual, Raleigh, N.C. (H. F. Judkins, 32 Ridgeway Circle, White Plains, N.Y.)

17–19. American Meteorological Soc., with Pacific Div., AAAS, Logan, Utah. (K. C. Spengler, AMS, 3 Joy St., Boston 8, Mass.)

18–21. College Physicists, 20th annual colloquium, Iowa City, Iowa. (J. A. Van Allen, Dept. of Physics, State Univ. of Iowa, Iowa City.)

18–22. American College of Chest Physicians, annual, San Francisco, Calif. (M. Kornfeld, ACCP, 112 E. Chestnut St., Chicago 11, Ill.)

19–21. Endocrine Soc., 40th annual, San Francisco, Calif. (H. H. Turner, 1200 N. Walker St., Oklahoma City 3, Okla.)

19–21. Society of Nuclear Medicine, 5th annual, Los Angeles, Calif. (R. W. Lackey, 452 Metropolitan Bldg., Denver, Colo.)

19–25. Scandinavian-American Meteorological Meeting, Bergen, Norway. (K. C. Spengler, 3 Joy St., Boston, Mass.)

21–22. Society for Investigative Dermatology, annual, San Francisco, Calif. (H. Beerman, 255 S. 17 St., Philadelphia 3, Pa.)

22–25. American Soc. of Agricultural Engineers, 51st annual, Santa Barbara, Calif. (J. L. Butt, ASAE, St. Joseph, Mich.)

22–27. American Inst. of Chemical Engineers, 50th anniversary, Philadelphia, Pa. (F. J. Van Antwerpen, AIChE, 25 W. 45 St., New York 36.)

22–27. American Soc. for Testing Materials, 61st annual, Boston, Mass. (F. F. Van Atta, ASTM, 1916 Race St., Philadelphia 3, Pa.)

23–25. American Soc. of Heating and Air-Conditioning Engineers, semiannual, Minneapolis, Minn. (A. V. Hutchinson, ASHAE, 62 Worth St., New York 13.)

Equipment

The information reported here is obtained from manufacturers and from other sources considered to be reliable. Science does not assume responsibility for the accuracy of the information. A coupon for use in making inquiries concerning the items listed appears on page 894.

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■ OUTPUT PRINTER for use with computers and data-handling equipment is capable of printing 10 lines of 120 alphanumerical characters per second. Up to 63 different characters are available. (Potter Instrument Co., Inc., Dept. S989)

■ STOPCOCK provides continuously variable flow adjustment over a broad range of liquid or gas flow. The stopcock consists of a precision-bore cylindrical barrel and a matching plug. A groove is used on the plug instead of the usual bore. Rotation of the plug moves it axially in the barrel, matching the groove to the inlet and outlet. (Wilmad Glass Co., Dept. S990)

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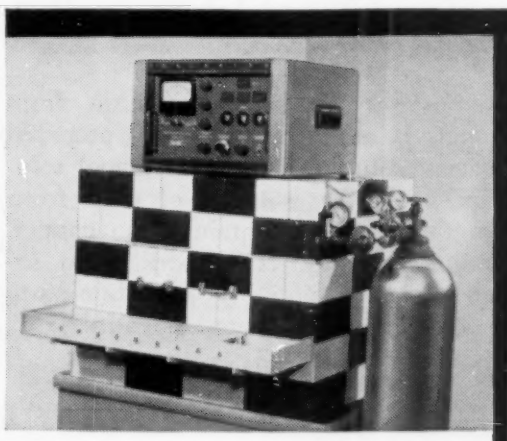

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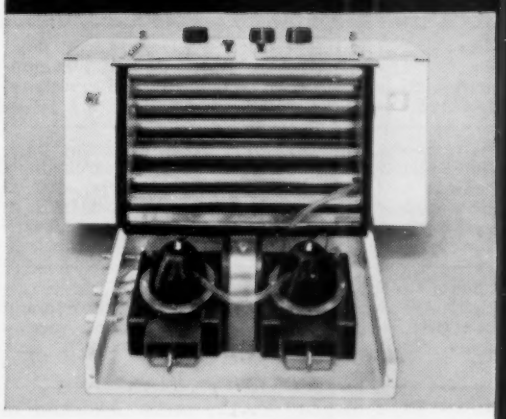

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